COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

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May 1951

Re-circulation steam generators in large Chicago dairy

Highlights of Midwest Power Conference

Chemical Conditioning of Cooling Waters

Selection of Pipe Supports

They keep coming back for more!

Companies that have bought VU Boilers *continue to buy them*. In fact, a substantial proportion of all VU Units, in service and on order, have been purchased by organizations whose selection reflects their own first-hand experience. *For example* —

A STEEL COMPANY now has a total of eleven VU Boilers in four different plants. Starting with three units in 1936, it has reordered three times . . . most recently in the fall of last year with an order for three more units.

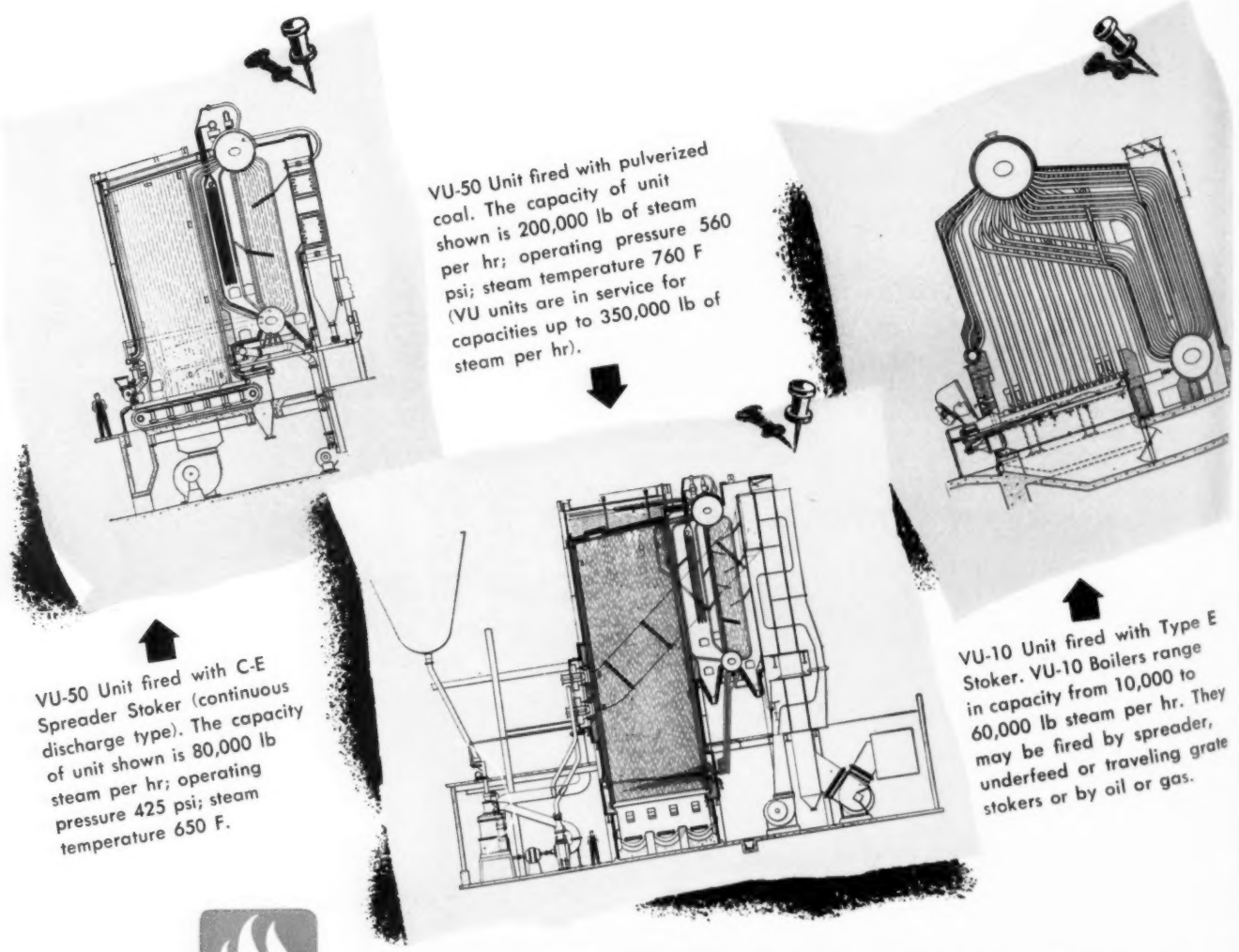
A TEXTILE MANUFACTURER ordered two VU Units in 1936. Another unit was installed in 1940 and a third in 1944. Still another textile company installed one unit in 1945, a second in 1949 and has just ordered another.

A REFINING COMPANY ordered one VU Unit in 1937, another in 1940 and another in 1949 for one of its plants; also two in 1942 and one in 1947 for another plant.

A SEWAGE TREATMENT PLANT in one of America's large cities is another consistent buyer of VU Boilers. Its initial order in 1936 was for two units. Since then it has reordered three times, and now has a total of seven VU Boilers in service.

• • •

The story is the same wherever you go — in all sections of the country American industry is ordering and *reordering* VU Units. Why? Because the VU's advanced design, sound construction and consistent reliability have become a service-proved answer to lower steam costs. Once you have a VU Unit in service you soon *know* why so many large steam users *keep coming back for more.* B-481A



VU-50 Unit fired with pulverized coal. The capacity of unit shown is 200,000 lb of steam per hr; operating pressure 560 psi; steam temperature 760 F (VU units are in service for capacities up to 350,000 lb of steam per hr).

VU-50 Unit fired with C-E Spreader Stoker (continuous discharge type). The capacity of unit shown is 80,000 lb steam per hr; operating pressure 425 psi; steam temperature 650 F.

VU-10 Unit fired with Type E Stoker. VU-10 Boilers range in capacity from 10,000 to 60,000 lb steam per hr. They may be fired by spreader, underfeed or traveling grate stokers or by oil or gas.

C-E

COMBUSTION ENGINEERING — SUPERHEATER, INC.

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COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

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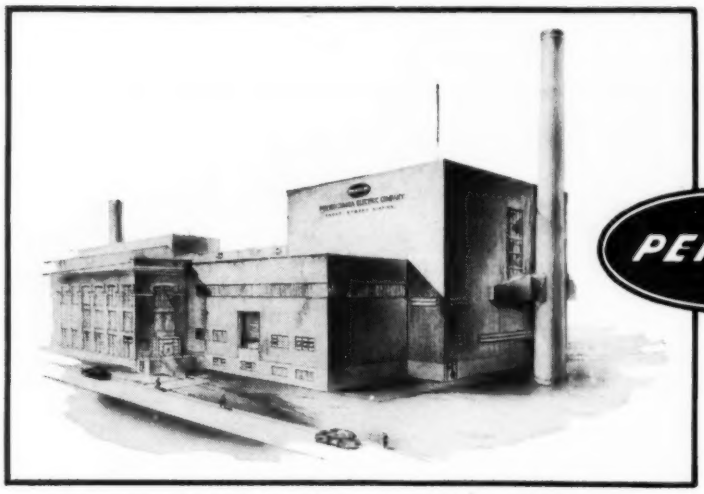
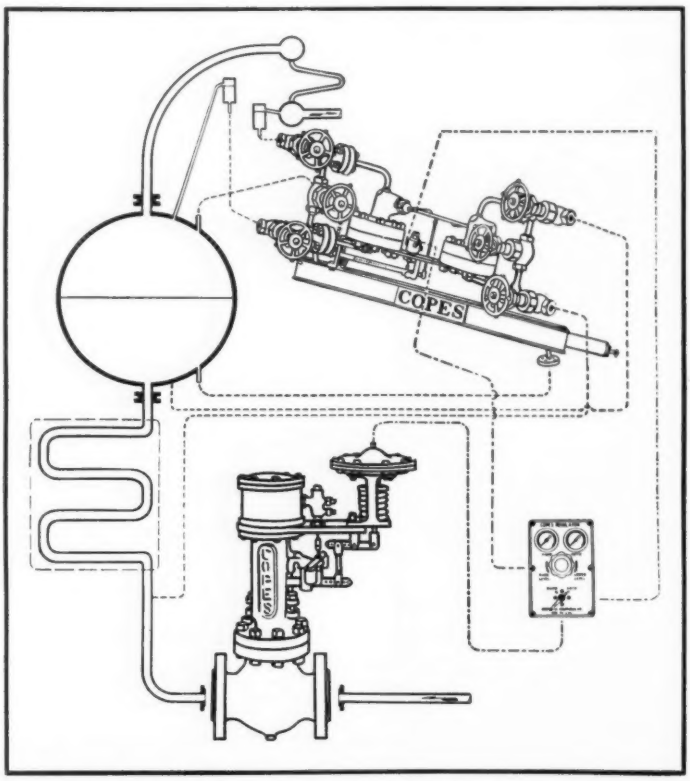
PENNSYLVANIA ELECTRIC CO. Places 6th order for COPES Multi-Element REGULATORS



Front Street addition includes two 1250-psi, 950-F C-E boilers, each rated at 400,000 pounds of steam per hour.



The COPES Balanced Flow Control, takes its control influences from steam flow, feed water flow and water level. Plant personnel can handle all maintenance easily; no need for "experts." The feed valve will stand up under *unlimited* pressure drops.

PENELEC

COPES Balanced Flow Control will be used for the 1952 Addition to Front Street Station of Pennsylvania Electric Company at Erie, Pennsylvania. This is the sixth time Penelec has ordered COPES Multi-Element Feed Water Control.

First installation was on the two original 675-psi boilers at Front Street, using two-element COPES Flowmatics. Two later orders placed Flowmatics on four 675-psi boilers at Seward. Two other orders equipped the four 875-psi boilers at Warren with COPES Flowmatics.

Now, for the Front Street Extension, Penelec has selected the COPES Balanced Flow—with control influenced by steam flow, feed flow and water level. This three-influence control is entirely independent of all other instruments and controls, and can remain on fully-automatic when they are out of service for routine inspection and care.

COPES Multi-Element Control is designed for the most modern boilers—for the most difficult operating conditions. Ask for proof of performance.

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Headquarters for **Feed Water Regulators, Pump Governors, Differential Valves, Liquid Level Controls, Alarms, Reducing Valves, Desuperheaters**

COPES

BOILER FEED WATER REGULATION

Editorials

Trends in Centralized Control

Centralized control of steam-electric stations has evolved to the point that some installations have been made in which the control room is physically isolated from the remainder of the plant Operators in such stations have no view of equipment nor can they hear the sound of plant operation Even for this extreme case questions arise as to how many functions should be centrally controlled, how much information should be recorded, and the desirable size of instruments to insure readability.

A discussion of centralized control at a recent ASME Metropolitan Section meeting revealed the existence of several schools of thought Although there is a pronounced trend toward the use of miniature instruments, a good case can be made for employing large dials to show some of the principal quantities conspicuously. In any case, it is possible to reduce greatly the length of panel boards by judicious use of miniature instruments and by location of recorders on the backs of panels or away from primary control functions.

One of the more debatable questions is the amount of power-plant "atmosphere" that should be allowed to permeate the control room. Should the room be completely soundproofed and isolated as an indication of the confidence that is being placed in the instruments? What about the psychological effect of being able to see the turbine and part at the boiler and to hear the usual plant noises? Some designers contend that instruments are reliable and that it is an unnecessary hangover from past operating experience to be able to see and hear in the accustomed manner. Television is one way of bringing realism to the control room and will probably be more widely used to view furnace conditions and drum water level.

Whether or not it should be possible to start up a station from the control room is a controversial question. Central stations have recently been placed in service which are designed for starting up from a central point, but there appears to be a trend toward simplification of control rooms. It is altogether possible that the extremes of centralization may have already been reached.

Atmospheric Pollution

Volumes have been written on smoke abatement and atmospheric pollution, and most of our more important cities have ordinances dealing with the subject. In fact, the Air Pollution and Smoke Prevention Association of America has just held its *forty-fourth* annual convention and many other engineering societies have devoted numerous sessions to it. From this one might infer that sufficient knowledge and experience had been gained to cope with the problem under almost any condition. Yet the past two or three years have seen renewed and widespread agitation in many localities throughout the nation, abetted by the local press and civic organizations, even in places where the atmosphere may be regarded as fairly clean.

One is sometimes led to question the extent to which some such campaigns may be justified, bearing in mind that in certain localities topography and prevailing air currents are contributing factors and that others result from operations which the public would be reluctant to give up.

In the more distant past, smoke was regarded as the principal offender but research has since revealed many others and the conditions under which they become offensive. There is no denying that important progress has been made during the past few years in identifying pollutants and ascertaining their behavior, as well as in pointing the way to their control; but with this knowledge it then becomes a question of how much the people are willing to pay for a reasonably free atmosphere and the extent to which they will extend continuous support to enforcement.

The June Graduate

In connection with the much-discussed problem of handling inductions into and deferments from military service, many opinions have been offered by educators and engineering groups. Although conflicting views have been expressed as to procedure, there seems to be general agreement as to the urgent need of more technical men to meet the needs of our stepped-up industrial preparedness program in addition to normal requirements.

In this respect, it has been estimated that openings in industry for young men with engineering training represent from two to three times the number that will graduate from technical schools and colleges this June. This situation offers the graduates considerable latitude in the choice of making connections.

Generally, the remuneration offered student engineers has advanced in line with the increased cost of living, but it would be a mistake for an applicant to permit such consideration to outweigh opportunities for gaining worth-while experience and subsequent advancement, particularly as some twenty-five per cent of the young engineers at present employed by industry are said to belong to the armed forces reserve. In other words, it is the long-range view that should prevail, consistent, of course, with a reasonable remuneration.

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Some Highlights of the Midwest Power Conference

WITH a registration around 1500 and an estimated attendance considerably in excess of that figure, the Thirteenth Midwest Power Conference, at the Sherman Hotel, Chicago, April 4–6, attained further importance as the outstanding annual meeting in the power field. Nearly sixty technical papers and addresses were given, of which only a few are here abstracted.

With **James D. Cunningham** presiding at the opening session, the address of welcome was given by **Henry T. Heald,** president of Illinois Institute of Technology, who discussed college enrollment in relation to military service. Despite a record in total graduations last June, enrollment last fall was under that of 1940; yet the demand for young engineers has reached a new high. This fact, together with military requirements, indicates an inadequate supply of engineering graduates for several years.

Mr. Heald was of the opinion that contemplated modifications of present draft plans will result in only a few 18- and 19-year students being drawn for military service; and estimated that student deferments would probably reach 350,000 per year for the whole country. He is adverse to adoption of accelerated college courses.

Response to Mr. Heald's address was made by Dean **L. G. Miller** of Michigan State College.

Next, **W. C. Mullendore,** president of Southern California Edison Company addressed the meeting on "The Engineer's Responsibility in the Fight Against Disintegration of the Foundations of Freedom." He charged that indifference and negligence of leadership in all walks of life must be charged with responsibility for the growth of that collectivism and concentration of power in the state which are undermining and destroying the self-reliance, self-discipline and independence of Americans. Our form of society cannot function if we delegate to a few so-called political experts the control and direction of human forces which, like the natural forces of electrical and atomic energy, may become destructive if not properly directed.

The National Power Situation

The final talk at the opening session was by **Walker L. Cisler,** executive vice president of The Detroit Edison Company, who discussed the national power situation. "The United States," he said, "has nearly as much installed electric generating capacity as all the rest of the world combined. This has made possible a standard of living far greater than that of any other nation.

"Recent studies forecast that the peak demand for electric power in the United States will increase from 61.8 million kilowatts in December 1950 to well over 70 million kilowatts in 1953—an increase of more than 25 per cent in a three-year period.

"Privately and publicly owned electric utilities responded quickly after the Korean outbreak and enlarged their already extensive expansion programs. On March 1, 1951, they had on order for delivery before the end of 1953 more than 25 million kilowatts of electric generating capacity in units of 4000 kw and larger, and additional capacity is being ordered as new requirements develop."

In addition to this, Mr. Cisler stated that more than 1.4 million kilowatts of steam turbine-generator capacity in units of 4000 kw and larger is on order for installation in industrial plants before the end of 1952. On the basis of orders on hand as of March 1, 1951, schedules call for the manufacture of 11.4 million kilowatts of additional capacity (thermal and hydro) in 1952 and 9.3 million kilowatts in 1953.

Unfortunately, the materials situation in recent months has not been normal and one of the most serious problems now facing the electric power industry is that of obtaining deliveries.

Two governmental agencies, the Defense Electric Power Administration and the National Production Authority, are responsible for the electric utilities. They have authorized use of priority ratings by the power equipment manufacturers for procurement of materials and have also authorized the utilities to use priority ratings for procurement of critical materials needed in their construction programs, as well as for maintenance, repairs and operations.

Mr. Cisler then reviewed the studies of power requirements and capabilities that have been carried out both by governmental agencies and by the Edison Electric Institute during the past ten years, including that conducted during World War II by the Office of War Utilities and later by the National Security Resources Board and Federal Power Commission.

While the reserve margin in 1948 was very low, the power surveys at that time indicated that the margin would increase progressively each year through 1951, on the basis of slightly over 6.5 million kilowatts of additional capability planned for each of the years 1949, 1950 and 1951. In fact, the margin reached 14.2 per cent in 1949, but unexpected high peak loads for the latter part of 1950 reduced the figure to 8.8. It was Mr. Cisler's opinion that the present expansion program should increase the national reserve capacity to a satisfactory level by 1953, although there is no definite assurance that the full effects of the defense program have yet been determined. For instance, the defense agencies have ordered an increase in aluminum production amounting to over 550,000 tons which will require about eleven billion kilowatts of energy annually and about 1,150,000 kw of capacity. Approximately 40 per cent of this additional power for aluminum production will be supplied by electric utility systems and the remainder will be supplied by self-generation.

Ridgeland Generating Station

The new Ridgeland Generating Station of the Commonwealth Edison Company, Chicago, was the subject of three papers comprising a session on Wednesday afternoon. The first of these, by **H. C. Schroeder** of Sargent & Lundy, dealt with mechanical design and construction; the second, by **J. C. Woods** of Commonwealth Edison Company, discussed the electrical design and construction; and the third, by **Ralph B. Gutekunst,** chief engineer of the station, related operating experiences.

This station, located on the Chicago Sanitary Ship Canal about 4½ miles from the center of the city, is designed for an ultimate capacity of 600,000 kw, in four 150,000-kw units operating at 1800 psi, 1050 F. The first half of the station, now in service, was designed without reheat and each turbine-generator is served by two boilers; the second half, scheduled for operation in 1953, will employ reheat and the unit system of one boiler per turbine. Each of the 150,000-kw cross-compound units comprises a 50,000-kw high-pressure element and a 100,000-kw intermediate and low-pressure element. The plant embodies several distinctive features.

The building walls of architectural concrete extend 23 ft above grade and from there on they are of insulated industrial aluminum siding mounted on a steel structure. Windows are provided only in the office end and ventilation is by mechanical means or lowered openings.

The plant is near a residential area and only 1¾ miles from the airport; hence, stack height became a conflicting problem. Previous tests had indicated stacks extending 300 ft above grade as desirable, but the Civil Aeronautics Authority agreed to only 213 ft, for which height calculations indicated a gas outlet velocity of 120 ft per sec as necessary in order to avoid backwash. The problem of backwash was solved by placing the stacks atop the switch house.

There was some question whether a satisfactory weld could be made between the 2¼-per cent chrome pipe and the 18–8 stainless steel nozzles; hence, a program was set up to test mechanical joints using these dissimilar metals. As a result it was decided to employ a "Bellowseal" joint on one unit and a "Pressure-Seal" joint on the other.

Operating Personnel

Mr. Gutekunst described the supervisory operating force as consisting of a chief engineer, an assistant chief engineer, a boiler-room engineer, a chief electrician, a master mechanic, two assistant master mechanics, a foreman and assistant foreman of coal handling, a supervisor of the generating station office, five shift engineers and five assistant shift engineers.

With one shift engineer and one assistant shift engineer on each eight-hour shift, it is necessary that they have the knowledge and experience required to supervise and direct all boiler and turbine room operations, as well as electrical switching. The same broad qualifications are required to a lesser degree by the senior operators and control operators. The total operating personnel numbers 140.

A net overall station heat rate of 10,100 Btu per kwhr is expected to be attained by the first two units with five stages of feedwater heating.

Water Treatment

J. A. Holmes of the National Aluminate Corp. presented a paper entitled "The Development of Organics for Water Treatment" in which he pointed out that higher boiler pressures and feedwater temperatures have made necessary the development of better organic materials. Tannins, starches and other plant extracts were satisfactory for use in preventing scale and corrosion until the 1930's. In investigating to find the constituents that produced results, it was discovered that some organics served best to prevent corrosion, while others forestalled deposits inside boilers.

The various uses of organics have been classified, and different organics have been selected according to their particular value for these uses, rather than trying to use one material for all purposes. For the past ten or more years much emphasis has been put on developing organics that are stable under high temperatures and produce better results. The author described research which resulted in the changing of previously available organics and the development of new synthetic materials.

"Organic Synergists in Foam Control" was the title of a paper by **C. M. Bodach** and **L. O. Gunderson** of Dearborn Chemical Co. Antifoams are of value in minimizing the carryover problem and in increasing boiler efficiency by permitting the carrying of higher boiler-water concentrations, though they are not uniformly efficient in all waters. It has been found that tannins have a powerful synergistic effect when combined with polyamide antifoams, in spite of the fact that tannins themselves have no significant antifoam properties.

In certain waters antifoams showed reduced activity which was believed due to adsorption of the antifoam on the sludge and scale. Tests were conducted on an experimental laboratory boiler to determine the mechanism involved. The following observations are significant:

1. Adsorbed antifoam is relatively ineffective.
2. Certain organics release antifoams adsorbed on other substances, permitting the antifoams to act freely in counteracting foam formation.
3. It is probable that similar action occurs in problem waters. The antifoam is made inoperative by adsorption on the sludge and then released by certain organics.

The authors believe that the best approach to increase the effectiveness of antifoams in problem waters is to find more efficient organic synergists. Laboratory tests have indicated that certain organic materials aid in the performance of antifoam. The power of adsorption is affected by different waters, sludge and forms of crystallization. Therefore, different amounts and types of synergist are required to obtain full effectiveness of the antifoam used. It may be necessary to add supplemental organic material. Usually it will be possible to find a suitable organic synergist-antifoam combination.

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A third paper on organics was entitled "Organic Agents in Boiler Scale and Sludge Control" by **J. J. Maguire** of W. H. & L. D. Betz. Where excellent and close external feedwater conditioning is maintained there may be no need for internal organic treatment to prevent scale and sludge, but in many industrial power plants, particularly where the feedwater hardness is high, organic materials have a definite place.

Usually, internal treatment is counted upon to precipitate the calcium salts, such as tricalcium phosphate, and magnesium salts, including magnesium hydroxide; but under some circumstances it is desirable to precipitate part of the calcium as calcium carbonate. Calcium phosphate, calcium carbide and magnesium hydroxide generally are the most desirable inorganic forms in which hardness can be precipitated internally in boiler water. However, even these will form some scale and sludge, depending on conditions, unless organic agents are employed. The more common agents are tannins, lignins, starches and seaweed derivatives.

Mr. Maguire then discussed the mechanism by which such organic substances function. Some act by dispersion of precipitates, and all exert some coating action on precipitated inorganic solids; but of prime importance is their effect in distorting crystal formations.

Also discussed were deposits in the preboiler system, such as feed lines, closed heaters and economizers where organic treatments are often found desirable. They are sometimes used as corrosion inhibitors, antifoam agents and embrittlement inhibitors, as well as for control of return-line corrosion and in cooling-water systems as algaecides; but, because of their more complex structures, their chemistry is not as clearly understood as that of inorganic agents.

Comparing conditions of a few years ago when hard scale was a serious problem in boiler operation with current problems of sludge in boiler tubes, **R. W. Liddell** and **L. C. Bishop** of Hall Laboratories, Inc., presented a paper entitled "Use and Misuse of Organic Water Conditioning Materials."

Sludge trouble, they pointed out, may be corrected by improving water softening, by changing boiler design to improve circulation and give better mixing of incoming feedwater with boiler water, or by adding chemicals to the boiler water.

Organic materials such as tannins, lignins and coal derivatives do their work by keeping the sludge suspended in the water, thereby preventing formation of harmful deposits. While this method works well in many cases, some difficulties have been experienced in instances where the organic material caused the boiler water to foam or where the material itself broke down in hot spots in the boiler and formed a scale. To decide when, or when not, to use organic materials requires considerable experience, knowledge of the particular boiler and good judgment.

"Experiences with Silica-Removal Demineralizer Plants" was the subject of a paper by **S. B. Applebaum** of the Cochrane Corporation, who reported that many demineralizers are now being installed without or instead of evaporators. The author surveyed developments in the field of ion-exchange, beginning with the use of sodium zeolite; then hydrogen zeolite which removes alkalinity in addition to hardness; then the weak-base anion exchangers which remove sulfates and chlorides but not silica; then the fluoride method which removes silica but is expensive and involves the possibility of fluorides being present in the final treated water and steam; and currently the strong-base anion exchangers used in the silica-removal plants now being installed.

At the Prairie Creek Station of Central Iowa Cooperative, Cedar Rapids, Iowa, a silica-removal demineralizer was installed to provide treated makeup water for two boilers rated at 230,000 lb of steam per hour at 850 psig, 890 F. Evaporators were purchased and delivered but they are not being used because performance of the demineralizer has been so reliable. The demineralizer has a capacity of 40 gpm and is a two-stage plant with a degasifier or decarbonator between the two stages. The raw water passes through the cation unit into the decarbonator and down to two 3000-gal storage tanks. From there it is pumped through the anion unit to feedwater storage tanks. The two 3000-gal storage tanks permit regenerating the cation unit while the anion unit continues to operate. This is necessary because the cation unit has a capacity of about 20,000 gal (based on average raw water) and the anion unit more than 120,000 gal between regeneration periods.

The decarbonator reduces free carbon dioxide from 275 to 3 ppm. Tests were run late in 1950 and disclosed that even when the cation unit is over-run to allow cation leakage, the silica did not leak through the anion unit. With water of the composition of Cedar Rapids well water which has a total hardness of 306 ppm, 11 ppm of SiO_2, 15 ppm of CO_2 and a pH of 7.4, the two-stage demineralizer can produce a feedwater having a total dissolved electrolyte of under 1 to 2.5 ppm, silica under 0.05 to 0.1 ppm, and a pH value of over 8.0.

The author also described an installation which is to be made in the Front Street Station of the Pennsylvania Electric Co. in which a demineralizer is to serve 650-psig boilers and 1250-psig topping boilers. This demineralizer will have a capacity of 400 gpm. A rubber-lined vacuum deaerator between the cation and anion stages will remove dissolved oxygen and free carbon dioxide to prevent corrosion in stage bleeder heaters and feed piping. The regeneration of the cation and anion units will be fully automatic and will be obtained by a motor-driven, pilot-actuated multiport valve. Complete instrumentation will be included so that the plant will be as automatic as possible to minimize attention during operation.

James Harlow of the Philadelphia Electric Co. and **V. J. Calise** and **M. Lane** of Graver Water Conditioning Co. presented a paper on the installation of a demineralizer at the Schuylkill Station of the Philadelphia Electric Co. In 1949 it was decided to connect this station to the steam-heat system of the company,

making available a potential supply of about 600,000 lb of steam per hour from the topping unit and low-pressure boilers in this station. It was at first proposed to use a type of feedwater treating plant similar to that of the Deepwater Station of the Atlantic City Electric Co. which comprises cold-process lime-Ferrisul treatment followed by salt-regenerated zeolite softeners to obtain 100 per cent makeup. However, there was some question as to what might happen to the Schuylkill high-pressure boilers if large quantities of water averaging 200 ppm solids and 2 ppm silica were used. Meanwhile, the Dow Chemical Co. was installing a large plant at Midland, Mich., employing demineralizers using anion and cation exchange materials, and estimates were obtained on the cost of providing similar equipment for the Schuylkill Station.

Studies were made of two-bed versus three-bed demineralizing systems. An important factor was the necessity for complete neutralization of acid wastes from the cation units before discharge into sewers. Calculations showed that three-bed operation with a weakly basic anion exchanger to remove strong acids and employing waste caustic from the third bed highly basic anion exchanger resulted in excess acid requiring neutralization. It was found possible to obtain a neutral waste water by proper adjustment of caustic-soda dosage with a two-bed system. Studies were also made of lime versus caustic neutralization in the three-bed system, styrene versus phenolic resin zeolites, and optimum quantity of regenerant dosage in the anion exchangers.

A decision was made to use the two-bed system employing a phenolic cation exchanger, regenerated by sulfuric acid, and a highly basic anion exchanger. This combination had the lowest initial cost and operating costs comparable with the three-bed system.

Philadelphia city water enters a 30,000-gal concrete storage compartment located below the operating floor. Three vertical shaft pumps pump the water through four hydrogen cation-exchange units for removing metallic cations and then to the top of two degasifiers which reduce the CO_2 concentration from approximately 40 ppm to 3–5 ppm. The degasifiers have clearwells having five minutes detention, from which point the water is repumped by means of acid-resistant centrifugal pumps through four strongly basic anion exchangers which remove all acids. The effluent contains about 1 ppm of electrolytes and less than 0.05 ppm silica and goes to the one million gallon lined-steel storage tank.

Every flow rate involved in the operating cycle is indicated, recorded and totalized on the instrument panels by orifice-type flow meters. Both the sulfuric acid and the sodium hydroxide used to regenerate the cation and anion exchange units respectively are introduced by means of eductors with automatic ratio control. The dilution-water and chemical-solution flows are also indicated, recorded and totalized.

Operating experience with the demineralizing plant, which has been in continuous operation since Dec. 15, 1950, has been satisfactory. The concentration of the boiler water is being held to 600 ppm and the blowdown is essentially the same as it was when the boilers were being fed with condensate and when 1 per cent makeup was supplied by evaporators.

Experiences with both internal and external feedwater treatment in packing-house boiler plants were related by **Myron B. Golber** of Armour & Co. Although many new developments in external softening plants have been reported, numerous steam generators continue in service after extended use of internal treatment, which still has advantages for many industrial installations.

Packing houses and other food-processing plants operate under special restrictions by reason of toxicity of some chemicals or quality-degrading effect of others, but otherwise can use any water treatment now available. Actual selection depends upon chemical, mechanical and economic factors. Plants operated by Armour & Co. have boilers ranging from hrt and four-drum Stirling units to modern two-drum steam generators with capacities of 125,000 lb per hr at 700 psig, 750 F. Steam uses cover hot water, comfort and process heating, electric generation and air and refrigerant-compressor operation.

As an example of the application of the chemical, mechanical and economic factors, the plant at Peoria was cited. Here a new three-drum waterwall boiler and previously inadequate treatment of hrt boilers required a complete review of available softening methods. In replacing the previous internal treatment, consideration was given to hot-process softening, zeolite treatment and a new internal treatment. Zeolite was eliminated because of the high carbonate content of the makeup water supply. Internal treatment was finally selected because the rate of return on the additional investment for hot-process softening was not found attractive, considering the major changes in feedwater piping and greater space requirements of the latter.

Armour plants have used most of the treatment methods available, but it appears that external softening is used principally where plant electric generation requires steam of a quality satisfactory for turbogenerator operation. Where the prime movers are not critical with respect to steam purity and much of the steam is used for process and heating, then the value of external softening is questioned.

The uses to which the steam is to be put is as much a consideration as is the protection of steam generators, auxiliaries and piping. Just as new machine tools do not always warrant replacement of older design, so external softeners cannot always be justified on the basis of obsolescence of internal conditioning. Both engineering analysis and economic considerations are required to determine the most advantageous treatment.

George H. Krapf of the U. S. Steel Co. discussed measures taken during the soda ash strike and shortage of the summer of 1950 to find some substitute for that chemical to be used in feedwater treatment. Investigation indicated that if the Scaife cold-process lime-soda softening plants could be converted to zeolite plants, the stocks of soda ash on hand could be made available to the hot-process softeners which would reduce the overall soda ash consumption by approximately 70 per cent. The author described how this

conversion was made and mentioned some of the experiences, difficulties and problems that were met and solved.

Spreader Stokers for Large Boilers

"Today, few engineers would have the temerity to install bituminous coal- or lignite-burning boilers of capacities up to 200,000 lb per hr without giving spreader stokers serious consideration. Actually, spreader-fired boilers of over 300,000 lb per hr capacity are in operation and capacities up to half a million pounds are being discussed."

This statement was made by **J. S. Bennett,** vice president of American Engineering Company, who attributed the trend toward spreader firing to the following factors:

1. Their simplicity.
2. Ability to burn a wide range of coals.
3. Freedom from clinker.
4. High sustained burning rates up to heat releases of 700,000 Btu per sq ft per hr of active grate surface and average furnace heat releases of 26,000 Btu per cu ft per hr.
5. Quick response to load changes.
6. Good boiler efficiency.
7. Low auxiliary power requirements.
8. Also, many spreader stokers have been installed in furnaces designed to burn gas or oil separately or in combination with coal.

Among the problems posed by spreader firing, he listed (1) fly ash which renders a collector a must for large units; (2) necessity for overfire air and intelligent operation to avoid smoke; and (3) attention to preheated air temperature to avoid clinkering. For lignites and high-moisture coals with high ash-fusing temperatures, a limit of 300 F was suggested.

Mr. Bennett illustrated and described a number of typical installations and suggested further the feasibility of applying spreader stokers at right angles to the conventional front and rear arrangement. This would permit large steam-raising capacity with comparatively narrow boilers by making the stoker as wide as necessary to provide the desired grate area.

Discussion

With reference to cross-firing, W. M. Dodds, a visiting engineer from England, observed that the quantity and composition of gas release does not vary from front to rear with the modern spreader stoker as it does with other types. He stated that cross firing for a relatively small unit of 35,000 lb of steam per hour has recently been employed at the new steam plant of the Benkema Strawboard and Paper Carton Company in Hoogezand, Northern Holland. This plant also employs a divided bunker which permits operation with low-volatile coal in conjunction with high-volatile coal.

Fireside Deposits*

"Minimizing of Fireside Deposits in Stoker-Fired Boilers Through Humidification of Combustion Air" was the title of a paper by **Paul Murphy, Jr.,** and **John D. Piper,** both of The Detroit Edison Company. This method consists of maintaining at least 16 lb of water vapor per 1000 lb of air fed through the fuel bed. Although humidification is not new, and at least 40 patents have been issued since 1876 on introducing moisture either below or above the fuel bed for various purposes, the authors believed this to be the first instance where controlled humidification has been used for the specific purpose of reducing high-temperature deposits on the heating surfaces of large stoker-fired steam generators.

Low absolute humidity periods result in rapid fouling of the heating surfaces, increased flue-gas temperatures, increased fan-power requirements, increased clinkering of the fuel bed, and increased maintenance costs.

For many years it had been known that superheater deposits formed more rapidly in winter than in summer; and in 1949, the possibility of correlation was carefully analyzed. This showed that the high-humidity periods coincided with periods of low stack-gas temperatures and high efficiency, and the marked differences in moisture content of the combustion air indicated a possible water-gas reaction that could reduce the volatilization of various compounds from the fuel bed that condense on the heating surfaces of the boiler.

Steam was used to add moisture to the combustion air; control was manual, and the amount of moisture added was adjusted for each 25,000-lb per hr change in steaming rate, each 5-per cent change in relative humidity and each 5-degree change in ambient temperature.

The first humidified boiler operated for a record of 133 days, and the stack gas temperature increased only 10 F. The steaming capability of this boiler after 133 days of operation was still 400,000 lb per hr. The boiler was then shut down for two days for minor stoker repairs. No cleaning was done, and it was put back into service and operated without benefit of humidification. After 29 days of operation, the steaming capability was reduced to 300,000 lb per hr and the stack gas temperature had increased 120 F.

In order to determine the rate of deposition, the composition of the materials that adhere to the superheater, economizer and air preheater, a probe sampler was used. Samples were taken while operating with varied quantities of humidification and under varied operating conditions. The results taken from these samples gave additional proof that humidification is beneficial.

The quantity of the deposit was lessened with the increase in humidity of the combustion air, and the color of the deposit ranged from nearly white for low humidity to nearly black with increased humidification. The selective volatilization of silicon compounds and general volatilization of all other constituents of ash was reduced with increased humidification.

Trend Toward Reheat†

In a paper entitled "The Trend Toward Reheat," **H. G. Ebdon,** vice president of Combustion Engineering—Superheater, Inc. pointed out that the reheat cycle

* A similar paper by the same authors was presented at the 1950 ASME Annual Meeting and a full abstract was printed in the February issue of COMBUSTION.

† This paper appeared in full in the April issue of COMBUSTION.

is not new in the power plant field, for some installations were made in the early 1920's. Although these early plants are still operating, there was a period of years in which metallurgical advances permitting higher steam temperatures and pressures took much of the interest away from the reheat cycle. That trend has been reversed since the end of World War II because of rising fuel costs and the development of dependable single boiler-turbine-generator units.

The Port Washington Station of the Wisconsin Electric Power Company was mentioned as a historic reheat installation which held the record of being the world's most efficient power station for about twelve years and proved the reliability of the large single boiler-turbine-generator unit. The first post-war reheat unit was ordered for this station in 1945.

1950 was the year in which reheat made its greatest impact upon the utility industry. Between January 1, 1950, and March 1, 1951, eighty-two reheat units aggregating 9,690,000 kw were placed on order, and one manufacturer reported that nearly 70 per cent of the utility business booked during that period was for reheat installations. Fourteen of the fifteen largest private utility companies, excluding those with 100 per cent water power resources, had reheat units either on order or in service at the beginning of 1951. Reheat units are also well distributed geographically in seven of the eight electric power supply regions established by the Federal Power Commission.

Soot Blowers

Recent years have witnessed consistent changes in soot blowers for power boilers, according to **D. E. Hibner, Jr.,** vice president of Vulcan Soot Blower Division. In years past a soot blower element, which was the part inside the boiler, consisted essentially of a piece of tube of carbon steel or heat-resistant alloy directing a steam jet in between the boiler tubes. There were limitations as to the temperature in which such elements could function; and, even when temperatures were below 1800 F, there was still rapid deterioration of the tubes or the blower element.

As higher gas temperatures were encountered, molten slag was caused to solidify on the boiler and superheater tubes and the blower element tube was limited in its cleaning capacity because there were as many as forty nozzles in one element. Therefore, each individual nozzle had to be small and the cleaning effect with slag was limited.

In order to avoid the high cost and maintenance on alloy elements, the first step was to remove them from the furnace when not in use; and the next, to equip an element with only two nozzles, thus concentrating the energy formerly divided among forty. There remained only to impart rotary and traversing motions to these two jets at the end of the element tube which is now called a lance. Thus, low maintenance is accomplished because the tube does not burn and proper cleaning is had because the energy is supplied where most needed. In fact, the retractable blower has replaced the old conventional rotary unit even in the cooler passes.

There has also been a change in the blowing medium in the last five years, said Mr. Hibner, through replacement of steam by air in an ever-increasing number of installations. While compressed air may initially be slightly more expensive, maintenance is apt to be lower and the quantity of water to be evaporated is less.

Small Plant Design

C. M. Stanley, of the Stanley Engineering Company, Muscatine, Iowa, confined his remarks to industrial power plants of 500 to 15,000 kw, in which requirements for process steam do not govern design. Compared with central stations such plants usually involve higher unit construction costs, lower pressures and temperatures, a lower capacity factor, less favorable sites, a higher ratio of reserve capacity and higher heat rates. The designer must endeavor to offset these handicaps by watching building costs, proper fuel selection and by establishing the correct heat balance.

With regard to steam pressures in the lower capacity ratings, 400 psi, 750 F is common; for capacities in the intermediate range up to 5000 kw, 600 psi, 825 F appears to predominate; and from here up to 15,000 kw many plants have gone to 850 psi, 900 F.

In such plants the trend is toward electric-driven auxiliaries, two stages of feedwater heating for the smaller installations, and up to four stages for the larger. Bituminous coal is the basic fuel for most such plants in the Middle West with a recent tendency to design for more than one fuel, although fuel oil can seldom be justified in that section. Spreader stokers are finding wider use and pulverized coal is seldom justified below 7500 kw. For heat recovery there is a tendency to rely upon air heaters without economizers. Many plants as small as 7500 kw employ automatic superheat control.

Initial investment, Mr. Stanley said, can be held down through semi-outdoor construction, employment of full allowable stress, reinforced concrete stacks, minimum duplication, and use of prefabricated components, where possible. Also, operating expense can be minimized through careful arrangement of equipment, the sizing of coal- and ash-handling equipment to permit such handling on one shift, a common boiler and turbine room and installation of such automatic controls as may be justified by the plant size.

Instrumentation and Control for Small Power Plants

P. S. Dickey, vice president and chief engineer of Bailey Meter Company, divided his treatment of this subject into four classifications, namely, small coal-fired boilers, small oil- and gas-fired boilers, medium-size industrial boilers and central-station power plants.

In the first group, covering a capacity range of 5000 to 30,000 lb of steam per hour, it was his opinion that there are many units where intelligent application of instruments and control can effect annual savings of 20 per cent or more of the cost of such equipment, and at the same time provide improved performance. Citing his company's 250-hp stoker-fired boiler plant as typical, he listed among the instruments used a novel Btu flowmeter which measures water flow through the boiler, temperature rise, and automatically computes and records the total Btu delivered to the

boiler. This is compared against air flow in the same way that steam-flow air-flow is ordinarily used in controlling combustion. There is also an independent furnace-draft regulator, a smoke recorder embodying automatic control of start and stop of the overfire air fan, a flue-gas temperature recorder and a draft gage.

For the package-type oil- or gas-fired boilers in sizes ranging up to 30,000 lb of steam per hour, the control panel contains the necessary instruments, steam pressure gage, steam-flow and air-flow meter, if desired, flue-gas temperature recorder and fuel and windbox pressure indicators, as well as combustion controls, burner lighting and safety controls, and the main fuel regulating and shut-off valves.

For oil-fired installations controls for oil pumping and heating with heavy oils may be installed on the panel.

Medium-size industrial steam plants vary greatly, depending upon the process and whether power is generated. The following instruments were listed by Mr. Dickey as economically justified:

Automatic Controls
- Combustion
- Feedwater
- Feed pumps

Recorders
- Steam flow
- Steam flow-air flow
- Steam and water temperature
- Flue gas and air temperature
- Drum level
- Feedwater flow
- Steam and water pressure
- Oxygen analyzer
- Smoke density
- Conductivity and pH

Indicators
- Steam and water pressure
- Fuel pressures
- Air pressures and drafts
- Oil temperatures
- Speed indicators, or ammeters for fans, pumps, feeders, etc.

For steam electric generating stations the trend is toward the unit type of plant with centralized control of mechanical and electrical equipment.

Estimating Ultimate Analysis

A study made to determine the correlation between the ultimate analysis and the proximate analysis of bituminous coals was reported in a paper by **Edward W. Jerger** and **John R. May,** of Iowa State College.

It was shown that the moisture-free higher heating value of the coal, HHV, may be estimated from the dry basis total combustible in the coal according to the relation:

$$HHV = K_1 \text{ (per cent combustible)} - K_2$$

where K_1 and K_2 are constants given in the accompanying table.

The carbon content was found to be directly related to the higher heating value as:

$$\text{Per cent carbon} = \frac{HHV}{K_3} \text{ (on "as received" basis)}$$

The available hydrogen, in per cent, is directly related to the carbon content and equals $\frac{\text{Per cent carbon}}{K_4}$.

Nitrogen appears in practically negligible amounts and may be assumed as K_5 (per cent combustible).

The sulfur content could not be correlated with either the higher heating value or some function of the proximate analysis. However, in the absence of a sulfur test, it may be approximated by using Du Long's equation in connection with the other equations presented.

CONSTANTS FOR EQUATIONS PRESENTED

Coal	VM K_1	42% K_2	VM K_1	42% K_2	K_3	K_4	K_5	K_6	K_7
West Virginia	230	6315	...	....	179.5	17.8	0.015	51.4	0.25
Pennsylvania	170	1700	...	....	179.5	17.5	0.015	46.8	0.15
Kentucky	211	5835	...	....	179.5	17.6	0.017	..	..
Illinois	149.2	600	113.9	−2350	180	18.2	0.015	49.4	0.21
Ohio	192	4200	...	....	180.6	18.4	0.015	..	..
Indiana	163	1650	...	....	179	18.0	0.016	..	..
Iowa	227.5	7450	230.8	7930	182	18.7	0.016	51.5	0.25

A correction was developed for the ash content of the proximate analysis to account for the change in ash composition before and after combustion, because of the FeS_2 present in the coal.

Gas Turbines

Several papers were devoted to the subject of gas turbines—one for power generation and the others dealing particularly with application to locomotive drive.

One of these papers was by **A. G. Mellor** of General Electric Company, who stated that his company has developed three types of gas turbines employing different cycles and having different operating characteristics. The first of these is a 3500-kw, simple-cycle, single-shaft machine with a thermal efficiency of about 15 per cent, originally designed for locomotive use but later adapted to central station power generation.

A 5000-kw compound cycle, two-shaft machine was later developed which, by use of regenerators to recover heat from the gas turbine exhaust and by intercooling between stages of compression, has a thermal efficiency of about 28 per cent.

The most recent development is a 3500-kw two-shaft machine, incorporating a regenerator and having a thermal efficiency of about 22 per cent.

All of these gas turbines have been designed to burn either natural gas or Bunker C and diesel oil, but must be shut down in order to change fuels.

Mr. Mellor's conclusions as to the most probable applications of gas turbines for power generation were as follows:

1. As base load units on small and medium-size power systems where relatively small increments of generating capacity can profitably be added.
2. As peaking plants on small and medium-size systems, where ease of starting and stopping makes it especially suitable.
3. In some cases where the relatively large amount of heat available in the exhaust gases from a simple-cycle gas turbine can be used to advantage in the heat cycle of an adjacent steam-electric generating station.
4. For railway-mounted mobile emergency power plants for rapidly restoring service.

Under title of "Progress Report on the Gas Turbine Locomotive," **Alan Howard** of General Electric Com-

pany stated that the Alco-G.E. 4500-hp gas-turbine-electric locomotive has been in operation on the Union Pacific Railroad since the summer of 1949, during which time it has traveled more than 100,000 miles, the major portion of which has been with Bunker C oil as fuel. This railroad has since ordered ten such locomotives.

High Acceleration of Russian Planes

At the Wednesday luncheon **Dr. John T. Rettaliata,** dean of engineering at Illinois Institute of Technology, commented on the comparative performance of Russian, American and British jet planes in the Korea theatre. The latest Russian jet fighter, MIG-15, he said, can step away from any U. S. plane now engaging it in combat. This superior acceleration he attributed to use of an "afterburner" installed in the tail pipe to augment the thrust, to "rocket assist" set off in the tail by the pilot when desired, or to "liquid injection" into the jet engine cycle.

It is believed that this Russian plane employs a centrifugal type jet power plant similar to the British Nene or Derwent engines, since the British several years ago sold the Russians a quantity of their latest jet engines.

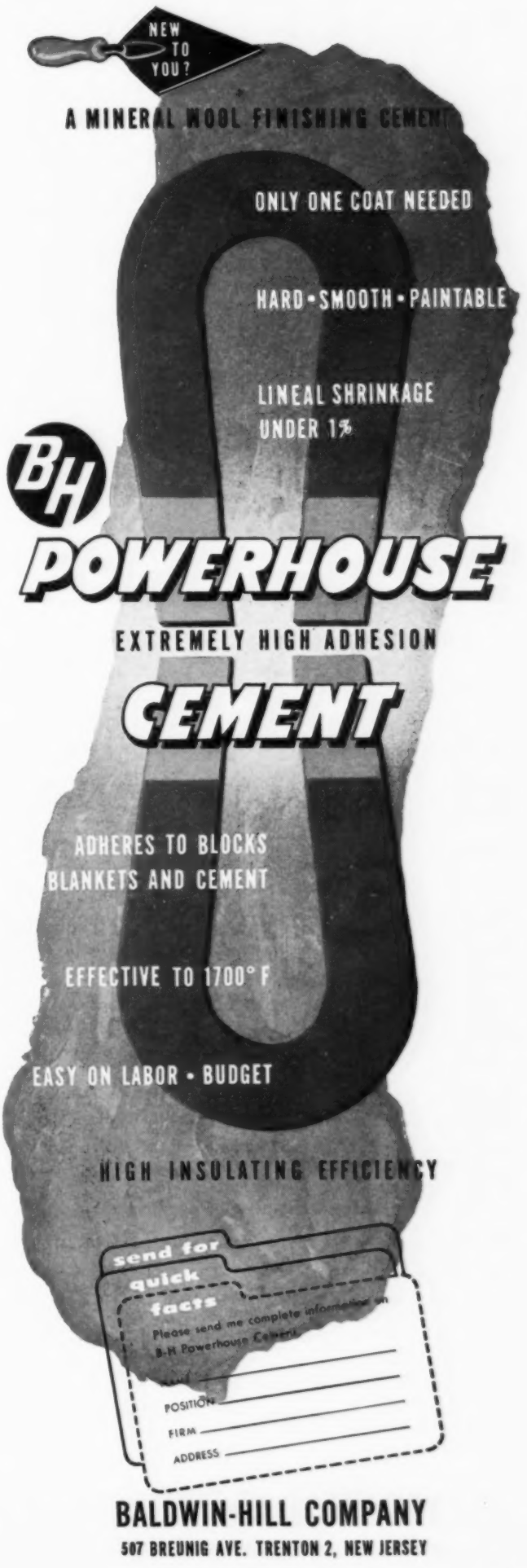
The most advanced type of American jet plane engaged in action in Korea is the F-86, with a top speed of 710 miles per hour. It probably out-performs the Russian plane except for acceleration, and in an encounter involving pilots of equal ability it is believed that the F-86 would show a margin of superiority.

Influence of Freezing on Heat Pump

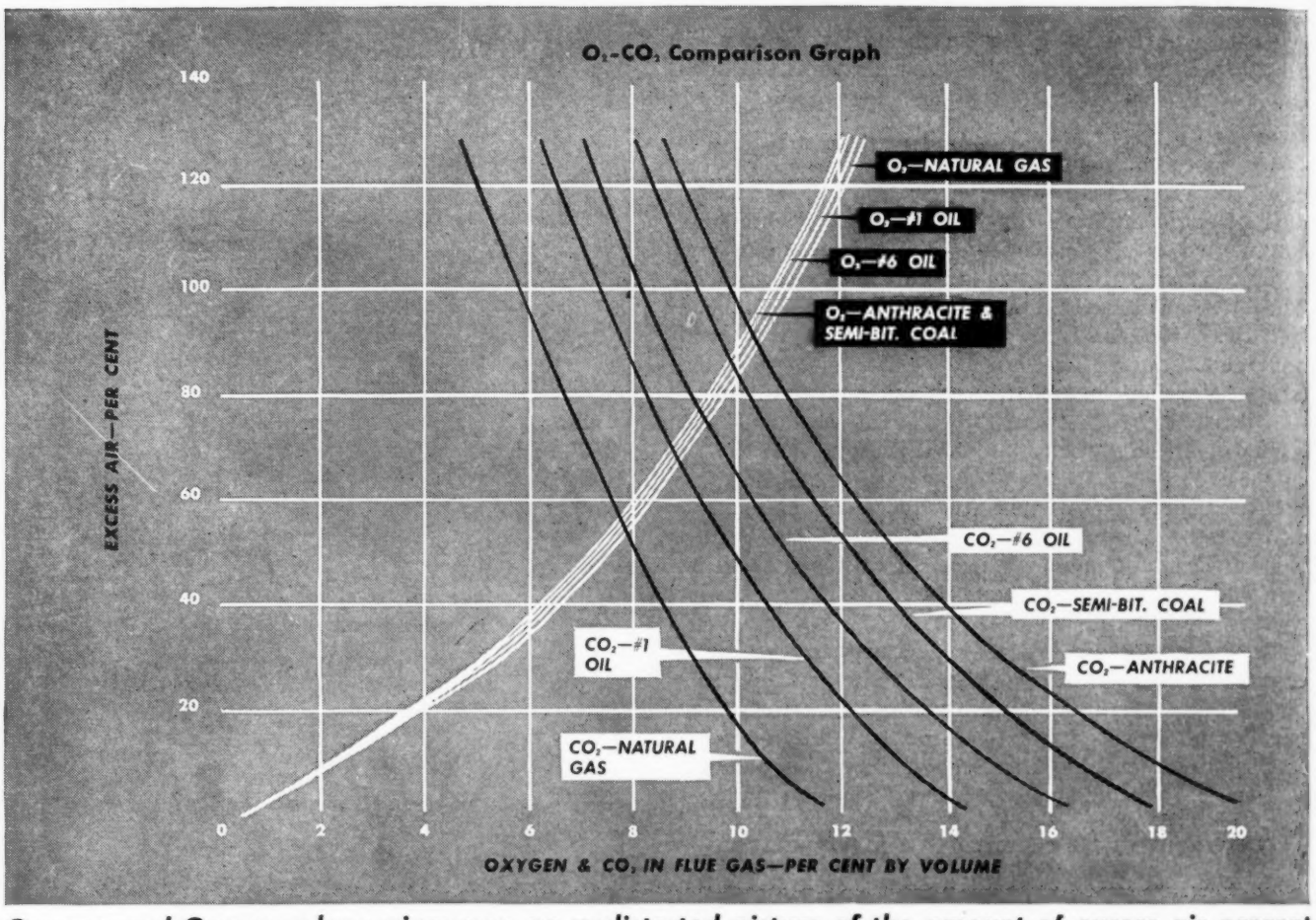
Armour Research Foundation has conducted research covering both the experimental and theoretical aspects of the heat pump as a practical heating and cooling device for buildings. It has been shown that a heat pump can be operated successfully on electrical energy and is able to compete with other fuels when current can be purchased for two cents per kilowatt-hour. The system can be operated with an engine-driven compressor in such a manner that about twice the heat now obtainable from a given fuel oil or gas can be delivered.

With such a promising future it might be asked why the heat pump is not widely used. The problem is to find a suitable source of heat for the evaporator coils. Until a few years ago the only heat sources given consideration were outside air and well water. The former is unsuitable in the colder regions of the United States. The latter is suitable where available, but the large quantity of water required eliminates its use in many localities. Recently attention has centered around the possibility of using the ground as a source of heat and the results at present appear very favorable, though many engineering problems remain to be solved.

As heat is withdrawn from the soil it is possible that the moisture in the soil surrounding the pipe will freeze. The effect of the freezing of moisture on the temperature distribution around a pipe when withdrawing heat at a constant rate from the surrounding earth was the subject of a paper by A. D. Kafadar, I. B. Fieldhouse, and R. A. Budenholzer which presented a method for predicting the radius to which the soil is frozen and for calculating the performance of a heat pump when freezing in the soil occurs.



How to burn Multiple Fuels efficiently



Oxygen and Oxygen alone gives you an undistorted picture of the amount of excess air present.

When switching from one fuel to another or burning more than one fuel at the same time, you can realize large savings with a continuous indication of Oxygen content in your flue gas—because Oxygen and Oxygen alone gives you an undistorted picture of the amount of excess air present.

This fact is borne out by the graph showing the relationship of excess air to CO_2 and O_2 in the flue gas of five common fuels. While the O_2 curves nearly coincide (especially in the important 30% excess air range) the CO_2 curves diverge widely.

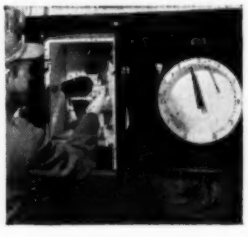
Large Savings Possible

This deviation was costing a medium sized refinery in Michigan $35-40 per day in boiler room fuel costs. Burning a combination of oil and gas they found that a combustion control system to handle their multiple fuel firing conditions would cost more than their small boilers.

They purchased a Hays Magno-Therm Oxygen Recorder, and immediately found that their boiler operation was so inefficient that the pen would not stay on the 0-10% chart. However, by operating with reference to the O_2 recorder they were able to reduce fuel costs enough *to pay for the instrument in 40 days.*

With the Hays Magno-Therm Oxygen Recorder you get:

Continuous, highly accurate indication and recording.
Complete compensation for temperature and pressure effects.
Freedom from chemicals or hazardous fuel burning in the analyzing process.
Swift, sure electronic operation.



If you are facing the problem of multiple fuel combustion, you will want a detailed copy of this O_2-CO_2 Comparison Graph as well as Hays Bulletin 50-829—describing the Magno-Therm Oxygen Recorder. Write for this free information.

THE HAYS CORPORATION
MICHIGAN CITY 1, INDIANA

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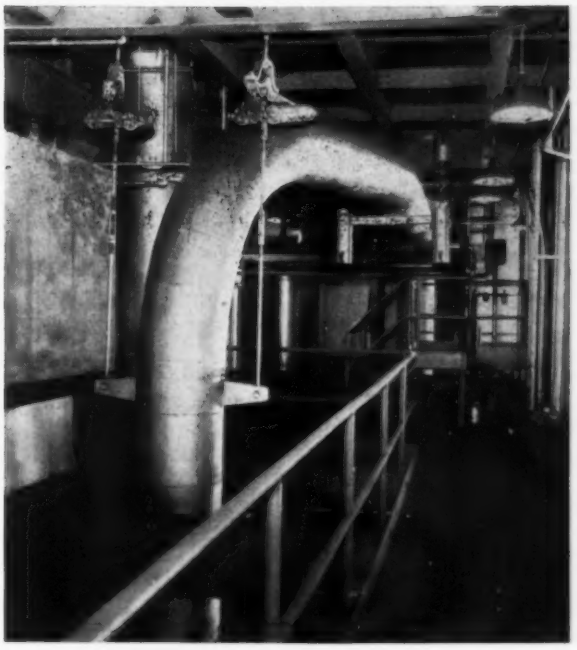
The Selection of Pipe Supports

In this paper before the ASME Los Angeles Section, on February 21, the author discusses the location of hangers and anchors, methods of attachment, sway bracing, vibration dampeners, thermal pipe movement and calculation of hanger loads.



Constant support of main steam line.

By E. W. STOTHART

Mgr., Pipe Suspension Dept.,
Grinnell Co., Providence, R. I.

IN THE field of pipe hangers and supports, limitations set by the ASA Code are general and do not go beyond the requirement that "Supports shall be such as to prevent, in operation, excessive stresses, excessive variation in supporting effort and possible resonance with imposed vibrations"; also that "The construction shall be such that complete release of the piping load will be impossible in the case of spring failure or mis-alignment." Thus the choice of hanger type, the means and methods of attaching the hanger, the arrangement of sway bracing and vibration dampeners, the procedure (analytical or experimental) in determining the flexibility and the stresses caused by expansion are left to the resourcefulness and preference of the designer. The requirements for safety are mandatory. They concern the selection of materials suitable for the service, the safety factor to be used in designing the equipment and certain limitations on minimum dimensions. At present, the ASA Code is being rewritten with the hope of incorporating some definite recommendations. Also, the U. S. Navy is completing, and will soon release, a new specification covering the support of ship's piping. These facts are mentioned to show that generalities are finally giving way to more specific requirements.

Systematic procedure for the design of pipe supports involves:

1. Determination and location of terminals, anchors and guides, with the forces acting upon them.
2. Determination of hanger and support locations.
3. Determination of thermal pipe movement at each support, or hanger, and at important terminals.
4. The selection of hanger types; i.e., spring, rigid or roller.
5. Calculation of hanger loads.
6. Selection and detail of hanger assembly.
7. Application of vibration control, sway bracing or earthquake protection.

Location of Anchors, Guides and Hangers

1. The location of anchors and guides is a direct responsibility of the piping design engineer, and only a secondary or a structural design responsibility of the hanger engineer. This detail, although simple, is the cause of much bickering and waste of time. The operating temperature and pressure within the pipe, coupled with the configuration of the system and pipe wall thickness, is the basic information necessary in performing a complex total pipe stress analysis. The pipe designer is responsible for layout of the piping so that the entire system will be within total pipe stress limitations. Thus the expansion forces acting upon a guide, anchor or terminal should be furnished to the hanger engineer by the pipe designer.

Even in cases where a complete stress analysis is foregone, it is a relatively simple matter for the piping engineer, who is more familiar with this particular phase of the work, to determine the thrust or forces acting on an anchor or guide. The pipe designer is also expected to specify the need for a solid anchor or guide that will permit movement in one or more directions while providing a restraint against movement in other directions. The problem then becomes the responsibility of the hanger engineer to design a pipe suspension system that will hold within total stress limits. Basic structural formulas may then be used by the hanger engineer to detail the required assembly.

Sometimes, with extremely flexible piping, the hanger engineer may want to add an anchor or guide in order to make the hanger system function as designed. This

should be done only after collaboration with the pipe stress or design engineer. There may also be times when an extremely long and heavy riser may be substantially supported near a point of zero vertical movement and on rigid hangers rather than taking the major portion of the pipe load on expensive spring hangers.

Under this system, sections of pipe between anchors and terminals may be treated as an individual or complete piping structure. Anchors or guides may perform a dual purpose; that is, they support the pipe weight and also provide the restraints called for in piping design.

2. Determination of hanger and support locations depends on the weight and size of the pipe, the position of valves or heavy fittings and the superstructure available for their support. Hangers should preferably be located at each valve or at other concentrated loads and close to changes of direction. When overhangs are unavoidable, the stresses produced should be determined and appropriately added to those caused by expansion and pressure. The spacing given in Table 1 is the result of practical considerations and will produce a total unit fibre bending and sheer stress of approximately 1500 psi.

TABLE 1—MAXIMUM SPACING BETWEEN PIPE SUPPORTS

Nominal pipe size, in.	1	1½	2	2½	3	3½	4	5	6	8	10	12	14	16	18	20	24
Maximum span, ft	7	9	10	11	12	13	14	16	17	19	22	23	25	27	28	30	32

It should be remembered that these are merely practical values based on standard beam formulas and the worst conditions, namely, a free span which will have far greater sag than on installations that may be looked upon as a continuous span. Table 1 is based on insulated pipe filled with water. The recommended values will produce $^1/_{10}$-in. sag between supports. This is not too great to insure drainage from a water-filled line. In many cases, total pipe stress limits will permit one to exceed the values of Table 1; however, from an appearance point of view, the sag would be noticeable. It should be mentioned that some state codes will not allow Table 1 for the reason that they call for pipe hangers to be spaced every 10 ft, regardless of pipe size, stress or widely accepted engineering practice.

Determination of Pipe Movement

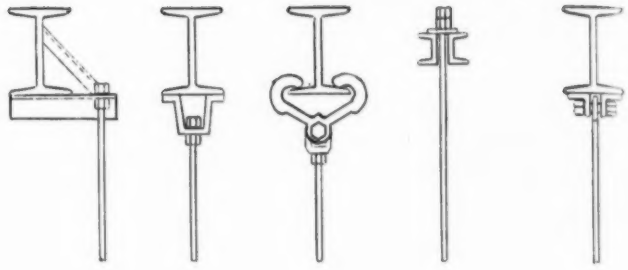
3. Thermal movement of the piping at each support or hanger is calculated from a simple law of physics. When a rod or pipe line is heated, it will expand an amount equal to its length times the coefficient of expansion for the particular material used.

TABLE 2—THERMAL EXPANSION OF PIPE MATERIAL FROM 70 F (INCHES PER 100 FT)

Material	Temperature, F										
	70	100	200	300	400	500	600	700	800	900	1000
Carbon steel or carbon moly	0	0.24	1.03	1.86	2.72	3.64	4.59	5.57	6.59	7.65	8.76
1 per cent chrome, ½ per cent moly	0	0.23	1.01	1.84	2.73	3.70	4.71	5.75	6.83	7.97	9.15

The Bureau of Standards, Grinnell "Hanger Load Calculation Booklet" or certain engineering textbooks will provide a more complete table of coefficients.

To simplify the work of determining the movement at each hanger, it is suggested that a two- or three-plane pipe structure can be considered as having square bends, The length of each individual leg times the coefficient,



Typical beam attachments

for all practical purposes, is the procedure that should be followed.

There are some piping structures where model test deflection studies or stress analysis deflections will not agree with the method; yet, in actual practice, the simple procedure is never far off, and in many instances is more nearly correct. Probably, commercial tolerances account for some of the strange observations that have been carefully checked in the field; or it may be that the inertia of the pipe will overcome the friction of molecular structure in the steel; hence, the calculated vertical deflection does not actually take place.

While the determination of pipe movement involves a complicated study of the entire system, equipment builders are also faced with a serious problem in determining the movement for various pipe connections. A modern high-temperature power boiler, particularly of the reheat type, consists of a mass of tubes that are attached to drums or headers which are, in most instances, flexibly supported. Recently, we were confronted with a boiler problem of supporting the entire radiant tube wall which moved $8^1/_2$ in. vertically and had a total weight of approximately 135,000 lb. This same installation has several other serious spring hanger problems, including a movement of $6^1/_2$ in. at the superheater nozzle outlet. This is cited to show that often the equipment connections will move, and one must be prepared to let the connecting piping move along with the boiler or turbine or pump nozzle. Equipment manufacturers are usually prepared to say just how much movement will take place at each connection, just as they will establish a stress limitation for these points.

Just a word of caution on "coldpull" and its effect on the vertical expansion of piping. Not long ago, an engineer stated that he was not going to use spring hangers on a certain installation because it was intended to take 100 per cent "coldpull." He went on to explain that the 2 in. of vertical movement would be cut from the 30-ft vertical riser for "coldpull." However, he failed to realize that a 29 ft 10 in. riser times the coefficient of expansion would still mean about 1.99 in. of movement to be supported on some kind of flexible hangers.

Hanger Types

4. Some engineers have attempted to specify the use of certain types of hangers on particular piping systems such as constant support hangers on the main steam pipe, or variable spring hangers on the boiler feed pipe. However, a procedure of this kind is definitely misleading.

Rigid hangers may be used on all pipe where there is little or no thermal movement. They are the most economical, and frequently it is not necessary to calculate the exact supporting forces required of each rigid hanger.

Horizontal axial movement of piping can be taken care of with pipe rolls. When movement is in the lateral horizontal plane and if rigid rod hangers are used, the swing of the pipe or the hypotenuse of the angle may dictate the use of a spring or flexible hanger that will not exert too much additional pull or lift. At all locations where springs, whether of the variable or constant type, are used a very accurate weight balance calculation should be performed. The detail of component parts that make up such assemblies will be covered in item 6.

Thermal Deflections

5. The thermal deflection of piping in modern high-pressure and high-temperature power stations has made it necessary to specify flexible supports, thereby requiring the designer to give considerable thought to the calculation of hanger loads for steam or hot pipe lines. Most manufacturers of power station equipment place limitations on the allowable loads at terminal points. Boiler and turbine manufacturers are especially concerned about the pipe weight on their equipment and sometimes will specify that the reactions at pipe connections shall be zero. Hanger engineers are interested in knowing the proper procedure to follow in calculating loads at various points of support on a pipe line.[1]

Piping Attachment

6. For simplicity this part will be considered under four groups:

(*A*) Attachment to pipe
(*B*) Attachment to building structure
(*C*) Sizing and selection of spring hangers
(*D*) Miscellaneous rods, clevises and intermediate parts

(*A*) Since a clamp itself is in direct contact with the pipe and subjected to operating temperature, the material specified must be suitable. For temperature of 850 F and above, an alloy steel is recommended because the allowable "s" values, as permitted in the ASA Code, will dictate the need for a very clumsy and heavy design if carbon steel material were to be employed. For temperatures from 450 F to 850 F mild steel may be used; also for these temperatures, cast-iron or malleable iron may be used when generally in compression only. For service temperatures up to 450 F, cast-iron or malleable iron may be used.

The attachment to the pipe must, of course, be suitable to support the total pipe or equipment load and the design should permit swing or lateral movement of the pipe. At least one part of the complete hanger assembly should have suitable facilities to adjust the elevation of the pipe after installation. It is more practical to have this feature of adjustment as a part of the pipe attachment design.

When high-temperature pipe rests on rolls or a trapeze assembly it is desirable to use a pipe covering protection saddle in order to keep from crushing the insulation.

(*B*) Attachment to the building structure may be accomplished in many ways with commercial beam clamps, concrete inserts, brackets fastened overhead and to the side of the structure. In many cases, special attachment or angle clips may be used. The necessary factors for the selection of building attachments depend upon the particular beam or supporting steel, and the ultimate strength of the device must be ample to support the load with a safety factor of at least 5 in order to comply with Code requirements. Here again it may be mentioned that a factor of 10 is necessary in certain states.

It is suggested that the design be such as to permit the load to swing freely and not restrain the normal thermal movement of the system. The ASA Code says that all materials used in the support of pipe shall be suitable for operating or service temperatures. A strict interpretation would mean that beam clamps that are far removed from high operating temperatures might have to be of alloy or other expensive material. It is quite possible that the rewrite of the new Code will say that "all materials subjected to operating high temperatures must be suitable for the service."

Drilling or the welding of lugs to a structural beam is frowned upon in many sections of the country; yet, it is growing in favor and specified by many important engineering concerns.

Spring Hangers

(*C*) The size and selection of spring hangers at one time was a major task for most engineers. In the first place, very few hanger engineers have had enough experience in designing a spring and invariably they will overlook at least one of the important factors. In choosing a spring to support a given load, he would overlook either the physical height and width of the assembly or the important load deflection rate of the spring, thus causing a considerable weight transfer from one hanger to another or from one hanger to the adjacent equipment. Even with a perfect design, a manufacturer will, sometimes, compel changes in order to satisfy his particular technique. The art of coiling springs rests with a few companies and for the most part is governed by their particular type of equipment, as well as the quality of spring wire.

Practically all major power plant designers recognize the importance of flexible pipe supports and appreciate the value and insurance of commercial spring hangers. For the most part, these hangers are economical and dependable. The saving in engineering time, as well as in erection expense, will far more than offset the surface difference in cost.

Most commercial spring hangers are furnished with a nameplate showing the exact load for which the hanger is designed. This detail has a permanent value to the operating engineer because he can always see, at a glance, that each hanger is supporting the load at the specified hot or cold position. If, for any reason, the pipe load or the building structure should settle, thereby bringing about a change in the supporting forces and reaction on the terminals, it could be noted and corrected by the

[1] An exact method that may be followed in calculating the required loads will be found on page 78 of Grinnell Catalog 10-D, 1950 edition.

operating personnel without having to refer back to tattered and dusty blueprints.

Where the piping is subject to vertical movement in excess of 1/2 in., due to thermal expansion, and also for the support of main steam piping at critical terminals, such as superheater outlet and turbine connections, pipe hangers must be of an approved constant support design. The following conditions are desirable:

(*a*) The sum of the pipe line weights must equal the sum of the supporting forces.

(*b*) The sum of the moments of piping weight acting at their centers of gravity and the supporting forces shall be equal to zero.

(*c*) Constant support hangers must be calibrated to support the exact load of the piping system.

Pipe hangers located at points that are subject to vertical thermal movement of 1/2 in. or less and not covered specifically in the preceding paragraph should be of an approved variable spring design.

Variation of hanger forces during operation shall range between 85 and 120 per cent of the actual load.

When a pipe distends because of thermal expansion, the flexibility of design may not be sufficient to prevent damage to connected equipment, the building structure, or the pipe itself if the line is improperly supported. Spring hangers are required for the support of high-temperature piping to prevent, or to maintain, within safe limits, the transfer of weight by the pipe supports as a result of thermal expansion. The type of spring hanger best suited to a given location depends on the location of the support and the flexibility and the operating conditions of the system.

(*D*) The size of hanger rod will in some cases be dictated by the standards of a pipe clamp attachment, building attachment or spring hanger parts. But in no case should it be smaller than the minimum standards specified in the Table 3.

TABLE 3—LOAD CARRYING CAPACITIES OF HOT ROLLED STEEL ROD; ASTM SPEC. A-107-42

Nominal Rod Diameter, In.	Root Area Thread, sq In.	Maximum Safe Load, Lb —Rod Temperature, F— 450	750
3/8	0.068	610	510
1/2	0.126	1,130	940
5/8	0.202	1,810	1510
3/4	0.302	2,710	2260
7/8	0.419	3,770	3150
1	0.552	4,960	4150
1 1/8	0.693	6,230	5200
1 1/4	0.889	8,000	6660
1 3/8	1.053	9,470	7800
1 1/2	1.293	11,630	9700

Turnbuckles, eye nuts, clevises and other miscellaneous connecting pieces should be selected to suit the particular installation.

Sway Braces and Vibration Dampeners

7. When necessary to prevent abnormal movement or vibration in pipe lines, sway braces or vibration dampeners are used. They should be installed in such a manner as not to interfere with or restrain the piping from normal movement resulting from thermal conditions. Use of sway braces of the energy-absorbing or instant-counterforce-acting type are recommended for control of undesirable pipe line movement.

In any piping system except static systems there are encountered movements caused by the following conditions:

1. Thermal expansion from
   (*a*) varying temperatures of the fluids
   (*b*) variable temperatures of the connecting vessels
   (*c*) externally applied heat
2. Wind, snow and ice
3. Movement of the support structure
   (*a*) pitch and roll of ships
   (*b*) miscellaneous mobile structures
4. Vibration for dynamic loading caused by
   (*a*) vibration of mobile structures
   (*b*) vibration of static structures
   (*c*) pulsation of the fluid
5. Earthquake

Thermal expansion creates differential movements throughout any piping system which must be restrained with solid anchors and guides or accommodated with flexible hangers. A system subjected to thermal expansion would usually be, as previously explained, analyzed first for stresses. Therefore, the movement, and points of restraint have already been determined for the critical points of the system and can be used directly for locating vibration control. Steam flowing from a horizontal run through a short radius turn, such as an elbow, into a long vertical riser may present objectionable impact forces which can be absorbed by the use of a sway brace.

Wind pressure and snow and ice loads should be included in the calculations for the strength and structural features of the supports for exterior piping, but should not be included in spring-hanger load calculations. Sway bracing should be installed to resist the prevailing winds.

If the entire supporting structure moves, as in the case of ships, then provision must be made for support when axes assume their maximum design variation from the vertical.

Horizontal supports in the form of guides or sway braces must be installed to support the components of the weight or mass according to the maximum pitch or roll. These braces are determined in much the same manner as hangers for stationary systems once the components are determined. It is customary practice in ship design to disregard pitch since it does not usually exceed a few degrees.

The subject of dynamic loading of any piping system resulting in vibration of part or all of the system is extremely complex. However, since it is a rare occasion when dynamic loading results in objectional, sympathetic or harmonic vibration, the problem can be greatly simplified by a brief analysis of the causes.

Dynamic loading of a structure, piece of equipment or segment of piping will create a frequency or frequencies which must be absorbed in all connecting masses. If the connecting masses do not have the same natural frequency, or first or second harmonics of this frequency then the dynamic load will be absorbed without objectional vibration. If some connecting mass should have the same frequency, or first or second harmonics, the dynamic loading (which has no direction) will create a sympathetic vibration therein. Sympathetic vibration can be prevented by altering the frequency of the dynamic loading, altering the natural frequency of the vibrating mass by applying a restrain-

ing force such as a sway brace, or divorcing the source of dynamic loading from the mass. The course to be taken can be decided by the relative cost of the three possibilities.

Sway braces or vibration control equipment, if it is to be effective, should be located in the true plane of the disturbance, and should be attached to the pipe at the point of maximum amplitude. It is really too much to expect to find suitable anchor points that will fulfill both of these recommendations, but one should keep in mind that the equipment is not being given a fair trial unless they are close to the desired plane and position.

The size of sway brace or forces required to control these problems need not be very great if of the energy absorbing or instant counterforce-acting type.

The attachment of special equipment for protection against earthquake seems worthless unless there is some way to predict the most likely direction of the disturbance. When this is possible the above suggestions for the control of sway or vibration will prove to be effective.

The only overall rule that might be suggested is to design all of the structural attachments, pipe attachments, hanger rods and miscellaneous parts to a factor of 10 instead of 5. Under these conditions springs should be designed for dynamic loading instead of static loading.

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CORROSION

Oxygen, one very active source of destructive boiler corrosion, is continuously detected and recorded by the Cambridge Gas Analyzer. The oxygen dissolved in the feed water is determined directly, and continuously recorded upon the Cambridge Dissolved Oxygen Recorder. The oxygen set free by dissociation in the boiler is determined by measuring the free hydrogen in the steam which is recorded upon the Cambridge Dissolved Hydrogen Recorder. Cambridge Analyzers are available in models for continuously recording either O_2 or H_2 separately or O_2 and H_2 simultaneously.

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Facts and Figures

Evan William Jones, an American, is credited with having developed the first successful underfeed stoker in 1889.

●

A peculiar property of "Discaloy," a high-strength high-temperature alloy now used for some gas turbine rotors, is that it is insensitive to notching.

●

The bituminous coal industry in the United States has been turning out more than ten million tons per week since the first of the current year.

●

A new electronic device to read test instruments at speeds up to 50,000 readings per second and record the readings on tape or punched cards has been developed by Arthur D. Little, Inc.

●

At the present rate of consumption and with current mining losses, it has been estimated by Anthracite Institute that recoverable reserves of Pennsylvania anthracite will last about 150 yr. These figures are based on U.S. Geological Survey figures.

●

There are now in service, or nearing completion, half a dozen gas turbines in electric utility plants in the United States. These range from 3500 to 5000 kw, although a 15,000-kw unit has recently been ordered for the Public Service Company of Oklahoma.

●

The temperature of the wall of a bare pipe carrying superheated steam is appreciably lower than that of the steam, and the higher the temperature and the lower the steam velocity the greater is this difference.

●

The Tennessee Valley Authority uses about 26,000 miles of aluminum cable, steel reinforced, to carry electric energy produced in its power plants.

●

A train carrying all the coal produced last year in American bituminous coal mines would stretch around the world three and a half times at the equator.

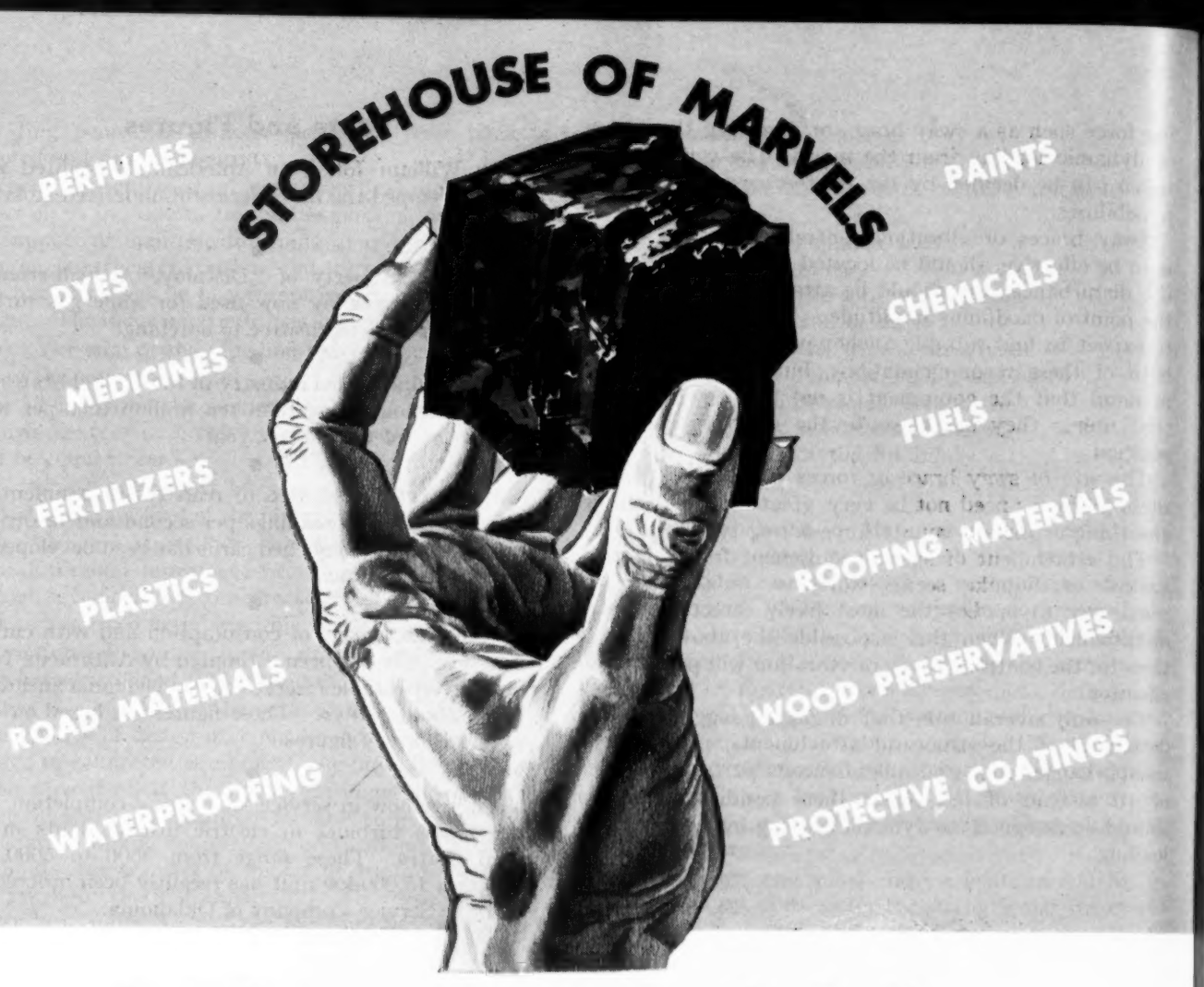
●

The Coal Exporters Association reports that about 20 per cent of all coal exported by the United States during the first quarter of this year went to Britain—the erstwhile foremost European coal-exporting nation.

●

According to figures recently released by the Federal Power Commission, peak loads on the principal electric utility systems in the United States for December 1950 reached a new maximum of more than 61,719,000 kw. This exceeded the December 1949 figure by 13.8 per cent.

Our supply of chrome ore from which chromium is produced comes largely from Turkey, South Rhodesia, New Caledonia, the Union of South Africa and the Philippines. Its principal power plant uses are in stainless steel and certain refractories. While, according to the U. S. Department of Commerce, there is no apparent shortage at the source, limited shipping space is affecting the supply.



. . . but the greatest marvel of all is its *HEAT!*

It's amazing to think of such things as perfumes, fertilizers, dyes and medicines, coming from a lump of coal.

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. . . heat and power for tens of thousands of commercial, institutional and industrial establishments in the populous eastern area is produced,

. . . twenty-five thousand steam locomotives still on the rails huff and puff and move the nation's freight.

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Chemical Conditioning of Cooling Waters

By JOHN P. KLEBER
Calgon, Inc.

Threshold Treatment of once-through and recirculating cooling waters is discussed and comparison is made between this internal method and external treatment of makeup water for cooling towers. Emphasis is placed on the capability of the former to prevent scale and control corrosion.

OF the various water uses in industry by far the most important from the standpoint of quantity usage is cooling water—water to cool condensers, heat-exchangers, furnace doors, tuyères, cookers, engines and compressors. Water for so relatively simple an application as cooling may involve problems in determination of water characteristics and source of supply, followed by complex conditioning procedures to control corrosion, prevent the deposition of scale, eliminate slime growths and protect cooling towers. An increase in temperature of cooling water can create a severe scale problem or tremendously accelerate the rate of corrosion of ordinary metals. An increase in temperature can even encourage the growth of microorganisms such as algae, slime molds and bacteria. While long subjected to oversimplification and neglect, proper treatment to overcome these problems is sometimes neither simple nor cheap.

An excellent presentation of cooling-water treatment in general appeared earlier in this magazine (1).[1] In that article the author stressed the preliminary external or primary treatment of the makeup water to open recirculating systems rather than the internal treatment of the actual cooling water. Since the majority of cooling waters at present are treated internally with polymeric phosphates, with or without the addition of acid and with or without external pre-treatment, a further review of the application of these phosphates as well as of other supplemental treatments is in order.

Application of a sodium phosphate glass such as the so-called sodium hexametaphosphate[2] in cooling-water treatment is termed "Threshold Treatment," both because of the relatively low concentrations used and because of the method by which the phosphate functions. This treatment of municipal and industrial waters was initiated less than fifteen years ago (2) (3), and its widespread adoption for cooling waters is attributable to its effectiveness and economy as well as to certain difficulties involved in the application of earlier methods of treatment for control of scale and corrosion.

Introduction of Langelier's equation, which occurred almost simultaneously with the introduction of Threshold Treatment, and the use of the Langelier index to denote when a water was neither scale-forming nor aggressive gave theoretical promise of eliminating the difficulties involved in pH adjustment for scale and corrosion control. Unfortunately, the use of the Langelier index has not proved entirely satisfactory in practice because of the limitations pointed out by the previous author (1). This index is not applicable with accuracy if the water contains more than 2000 ppm of total solids, less than 50 ppm of hardness or if water temperature rises above 170 F. The basic limitations, however, derive from the fact that the saturation index is a measure of the tendency to precipitate or dissolve calcium carbonate but not of capacity. Neither does it consider the basic corrosivity of the water, nor does it overcome the fact that cooling waters must of necessity involve more than one temperature. Despite improved techniques in applying the index, a desirable saturation index at one temperature is not desirable at any other temperature since either too much scale will be formed or no possible protection from corrosion will be provided.

Once-Through Cooling Waters

Treatment of once-through cooling water is similar to that of municipal water supplies. The three main functions of treatment are to control corrosion, to prevent formation of troublesome deposits whether of calcium carbonate, silt, or iron or manganese oxide, and to prevent growth of bacterial slimes. For the latter purpose either continuous or intermittent chlorination has proved most effective, and least expensive in the long run.

Threshold Treatment with sodium hexametaphosphate has proved effective both in preventing deposits and in minimizing corrosion. While pre-treatment of the water consisting of aeration, filtration, or softening can eliminate deposits in the cooling system, it is expensive both in installation and operating costs and may even create or aggravate the problem of corrosion. On the other hand, if a river water high in turbidity or a well water containing more than 5 or 10 ppm of dissolved iron or manganese must be used, then preliminary sedimentation or filtration may be the only economical means of preventing deposits of silt or metallic oxides. While metaphosphate will disperse silt and stabilize dissolved iron and manganese so that these substances will not precipitate in the cooling system, the treatment may not be economical for higher concentrations.

[1] Figures in parentheses pertain to references at end of article.
[2] The sodium hexametaphosphate referred to in this paper is Calgon, a commercial sodium phosphate glass containing 67 per cent P_2O_5. Results obtained with other polymeric phosphates or other molecularly dehydrated phosphates would be in qualitative but not quantitative agreement.

Stabilization to Prevent Scale

Metaphosphate prevents the deposition of relatively insoluble salts, such as calcium carbonate and calcium sulfate, when the water is heated by stabilizing a condition of rather marked supersaturation with respect to these insoluble salts so that they do not precipitate. This mechanism has nothing whatsoever to do with the complete "sequestration" of the hardness in the water by the metaphosphate as utilized in domestic practice. Threshold Treatment does not soften the water with respect to soap. Some idea of the maximum amount of calcium carbonate or bicarbonate hardness that may be stabilized with metaphosphate at various temperatures can be gained from the literature (4) as shown by Fig. 1 which gives the results of laboratory tests of heating samples of water with varying amounts of hardness to temperatures up to the boiling point for one hour.

In practice once-through cooling water is seldom held at the elevated temperatures for such long periods. Moreover, natural waters will seldom exceed the maximum hardness values shown by the treated curve so that for once-through systems this treatment is usually all that is required to prevent the formation of scale. If calcium carbonate does precipitate in the presence of insufficient amounts of metaphosphate for complete stabilization, the metaphosphate so interferes with the crystalline structure of the salt that the precipitate usually takes the form of a loosely adherent sludge rather than that of a dense scale.

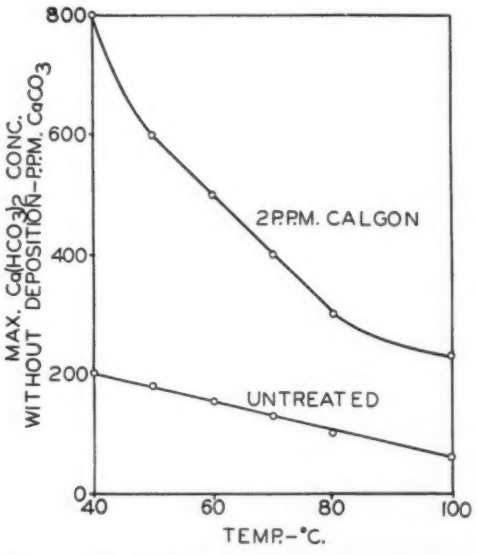

Fig. 1—Maximum bicarbonate hardness which can be maintained without deposition with and without 2 ppm Calgon as a function of the temperature

Control of Corrosion

The mechanism by which glassy phosphates control corrosion is quite different, depending upon adsorption upon the metal surfaces rather than upon the crystal nuclei. These phosphates form a protective film over metal surfaces in the water system which effectively isolates the metal from the corrosive elements. This film forms readily at pH values above 5.0 and is of molecular dimensions. Since the film does not build up to an appreciable thickness it does not impede the flow of water. The protective film is not permanent, however. It is continually being broken down and repaired and therefore a continuous supply of fresh phosphate is necessary. Somewhat higher concentrations of metaphosphate are required for corrosion control than for scale prevention, particularly at the higher temperatures, since the rate of corrosion is tremendously accelerated at these elevated temperatures.

TABLE 1—WATER REQUIREMENTS OF RECIRCULATING COOLING SYSTEMS WITH 10 DEG F TEMPERATURE RISE FOR DIFFERENT CONCENTRATIONS OF MAKEUP WATER

Per cent of makeup removed from system as windage and waste	Number of times makeup water is concentrated	Makeup, pounds of water required for every pound of steam condensed or every 1000 Btu's of heat load		
		Evaporation	Windage and waste	Total
10	10.0	1.0	0.11	1.11
20	5.0	1.0	0.25	1.25
30	3.33	1.0	0.43	1.43
40	2.5	1.0	0.67	1.67
50	2.0	1.0	1.0	2.0
60	1.67	1.0	1.5	2.5
70	1.43	1.0	2.33	3.33
80	1.25	1.0	4.0	5.0
90	1.11	1.0	9.0	10.0
98	1.02	1.0	49.0*	50.0
100 (once-through system)	1.00	0	100.0	100.0

* With the blowdown approaching the rate of recirculation in this case some heat would naturally be lost in the blowdown and slightly less evaporation would be required.

It is generally accepted that, as the pH of water is reduced below 7.0, the corrosion occurring in a water system tends to proceed more uniformly and the corrosion products are carried away by the water. On the other hand, at the higher pH values, particularly those between 7.0 and 10.0, the corrosion tends to be localized, the corrosion products being precipitated in place as tubercles which are pervious to water and therefore have little effect in stifling further attack. The resulting pits may soon penetrate the pipe wall; also the tubercles soon impede the flow of water and cause increased pumping costs or decreased carrying capacity. Thus, tuberculation and pitting are by far the most serious type of attack from the standpoint of dollars and cents.

Hatch and Rice (4) demonstrated that Threshold Treatment decreases the total corrosion without changing the type of corrosion characteristic of the higher and lower ranges of pH. This is shown in Fig. 2 in which the rise in head or pressure to force a constant flow of water through small-diameter black iron pipe is used as a measure of the tuberculation occurring. The same investigators had earlier demonstrated that increase in pH value by itself has no great effect in reducing the total corrosion occurring until a value of 10.0 is reached; metaphosphate, in contrast, is equally effective at all pH values above 5.0 or 5.5 (5).

In view of these considerations, supplementary adjustment of the pH value of the water with alkali is not necessary in connection with this treatment, and, in fact, is not desirable if the natural pH is as high as 6.0. This basic principle has worked so successfully that many operators now deliberately add acid to their cooling water to obtain better control over the residual tuberculation and pitting. Unfortunately, the addition of acid to once-through cooling waters can be expensive.

Recirculating Cooling Waters

There are two completely different types of recirculating cooling systems; the open type employing a spray pond or cooling tower in which cooling is by evaporation, and the closed type where no evaporation occurs and

there is little or no addition or loss of water from the system. Use of the closed system is limited and, inasmuch as this type merely transfers the cooling problem from possibly an engine jacket to a secondary heat-exchanger and an open-type cooling system, it will not be considered to any great extent in this discussion. Scale deposition is seldom a significant problem in a closed system even though a hard water is employed because there is no continuing addition of scale-forming salts to the system. However, corrosion is frequently encountered, in which case simple treatment of the water with 500 to 1500 ppm of chromate (6), or an oxygen scavenger such as sodium sulfite, if the system can be made nearly airtight, will usually solve the problem. In this case use of more expensive inhibitors can be warranted since the consumption is not great and it is seldom advisable to employ phosphates as there is no overflow to waste to limit the build-up in phosphate concentrations so there is some danger that calcium phosphate might precipitate in the system as a sludge or soft scale. Inhibitors such as sodium nitrite could be used in these systems although nitrites, like chromates, would be more effective with condensate or demineralized water.

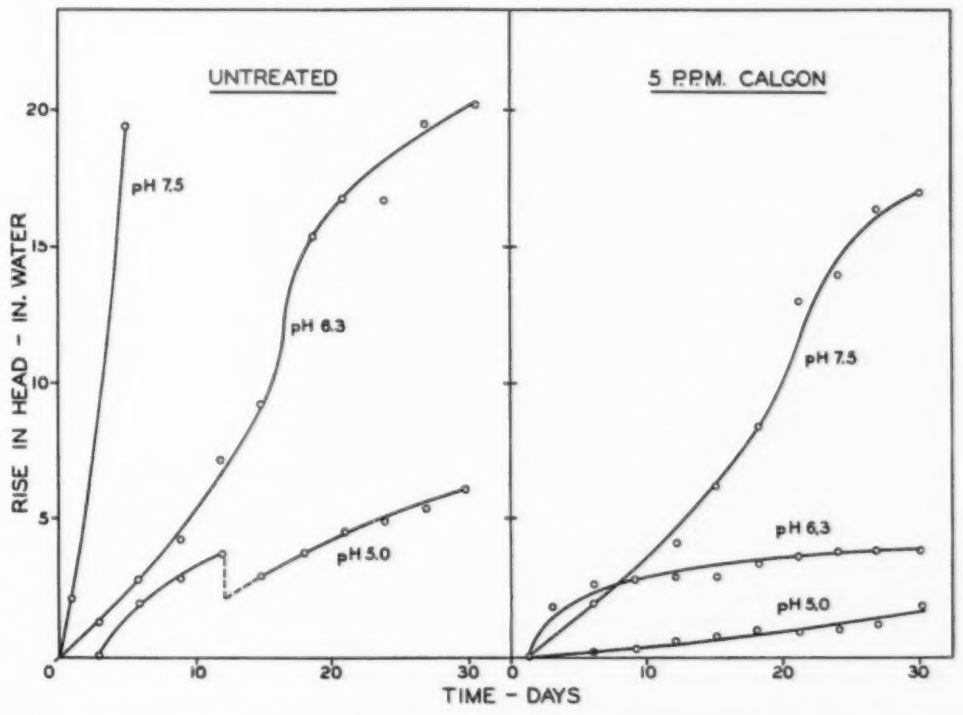

Fig. 2—Influence of pH and glassy phosphate on tuberculation of black iron pipe

Makeup Water Requirements

Since considerable evaporation occurs in the cooling tower or spray pond of an open-type recirculating system, the mineral-solids content of the recirculating water will be much greater than that of the makeup water as the evaporated water will naturally leave its solids content behind in the remaining water. Thus it may be said that the makeup water is concentrated in the system. Both windage loss and blowdown tend to decrease or limit the concentration as in both cases mineral solids as well as water are removed from the system. As windage loss is relatively constant, concentration of makeup is regulated by additional blowdown.

The amount of makeup water required for any recirculating system will be determined by the number of concentrations of the makeup that can be tolerated in the system without encountering serious scale deposition or corrosion. As shown in Table 1 the amount required increases only moderately as the number of concentrations is reduced to a certain point. For comparison, figures are included for a once-through cooling system. Since one pound of cooling water must be evaporated for every pound of steam condensed the evaporation remains virtually constant for all but the once-through system where no evaporation occurs and cooling is by a change in the sensible heat of the water only. In this latter case a 10-deg F rise through the heat-exchanger is assumed and the comparison would not be entirely typical of winter operation as temperature of the makeup might be much less than that of water returning from a tower.

This table shows the inherent differences between once-through and recirculating cooling systems and also demonstrates why no comparison of cooling-water treatments can be made solely on the basis of chemical costs per thousand gallons of water treated. The amount of makeup water required and its unit cost are factors usually as important as the chemical costs per thousand gallons. Amortization of capital expenditures for cooling towers and water-treating equipment must also be considered before deciding which type of system to use as well as what treatment to employ.

From the standpoint of water conservation, little is gained on a percentage basis by concentrating a makeup water more than five times in a recirculating system. In fact, no very great percentage of makeup water is saved by concentrating more than two times. Certainly concentrations of more than 5 or 10 times cannot be

justified except possibly in a few extreme cases of water scarcity. Even though condensate or demineralized water were used as makeup, it must be remembered that a cooling tower is quite efficient as an air washer, removing most of the dust, fly ash and acid gases from the air passing through it. Consequently a certain amount of blowdown is advisable to keep the system free of these impurities and suspended matter or silt introduced, as well as to regulate concentration of the dissolved salts.

Treatment of recirculating waters becomes somewhat more complicated than treatment of once-through cooling waters since allowances must be made for the concentration of the makeup water in the system but the basic principles remain the same. However, a soft corrosive makeup water, by concentration, may become scale forming and virtually non-corrosive while a relatively unbuffered makeup water with a high pH may become corrosive because of the absorption of acid gases and the resultant drop in pH value.

Stabilization to Prevent Scale

Possibly the most extensive application of Threshold Treatment in connection with recirculating cooling systems is to prevent deposition of calcium carbonate scale. By stabilizing concentrations of bicarbonate hardness far in excess of those normally possible, this treatment will permit greater concentration of the makeup water without danger of scale deposition.

In this treatment it is only necessary to maintain a residual of 2 or 3 ppm of metaphosphate in the recirculating water at all times. This is best accomplished by means of a continuous feed of metaphosphate to the sump of the cooling tower near the suction intake of the circulating pumps. A constant feed is not absolutely necessary since minor irregularities will be evened out in the recirculating system. As a matter of fact, batch feed, while not recommended for best results, can be used satisfactorily provided additions are made at least three or four times a day.

When the molecularly dehydrated phosphates are dissolved in water there is a gradual rehydration of these compounds to form the original orthophosphates which are much less effective in preventing scale. The greater the blowdown from a recirculating system, the less time the makeup water containing the dehydrated phosphate stays in the system. This means there will be less rehydration or reversion of the phosphate so that for any one system there will usually be little difference in the pounds of metaphosphate required per day to maintain the necessary concentration in the circulating water regardless of blowdown. Thus with four or five concentrations of the makeup water it is necessary to feed as much as 10 ppm of metaphosphate based on the makeup while with only 1.5 concentrations a feed of only 2 or 3 ppm may be sufficient.

While relatively high concentrations of bicarbonate hardness can be stabilized with metaphosphate, there are practical limits which should not be exceeded. For the relatively low-temperature systems in power plants, experience has proved that it is safe to carry as much as 450 to 500 ppm of bicarbonate hardness, while in the relatively high-temperature systems of oil refineries and other process industries it may not be possible to carry more than 300 ppm. Unless makeup water is extremely scarce or expensive it is usually most economical to limit the concentration of bicarbonate hardness by providing sufficient blowdown, rather than by feeding acid, particularly when it is still possible to carry at least two concentrations since it will be remembered that proportionately less water is saved at higher concentrations.

Reduction of Alkalinity

If it is not possible to provide this additional blowdown the same effect can be obtained by using sulfuric acid, acid salts, or fumes from burning sulfur to neutralize the excess bicarbonate or by employing pre-treatment to soften the makeup water either with lime or with base-exchange materials. If primary softening is employed care should be taken to design the system so that excessive sodium alkalinity is not left in the water. Such alkalinity not only can cause serious delignification of wooden cooling towers but it has also been known to cause rather severe dezincification of brass condenser tubes. Moreover, high sodium alkalinity tends to reduce the solubility of calcium carbonate.

When adding sulfuric acid to recirculating waters in conjunction with Threshold Treatment it is still considered best not to concentrate the makeup water until the solubility of calcium sulfate (about 2000 ppm) has been exceeded. This is because few operators consider it advisable to deliberately introduce another potential problem of calcium sulfate deposition which could occur if the metaphosphate residual dropped too low. However, slightly higher concentrations of metaphosphate, on the order of 5 to 10 ppm, are quite effective in preventing the deposition of calcium sulfate and, by providing such residuals, many operators in the far west are successfully carrying calcium sulfate concentrations that are several times the normal solubility.

Control of Corrosion

From the foregoing discussion regarding scale prevention one might infer that corrosion is seldom a problem in recirculating cooling systems. That is definitely not the case. Corrosion has always been a widespread problem, particularly in the higher temperature cooling systems of oil refineries and other process industries. When corrosion does occur in a recirculating system it tends to take the form of serious tuberculation and pitting because of various factors such as concentration, continual aeration, and relatively high pH values. Even in the case of unbuffered makeup waters where the pH value drops rapidly due to the absorption of acid gases, pitting is likely to be severe. Tuberculation and pitting are extremely serious in industrial cooling systems both because water passages are usually small and because relatively thin-wall steel or alloy tubes are used for transmission lines and for heat-exchange surfaces.

For controlling corrosion in recirculating systems the same basic principles of corrosion control apply, as discussed in connection with once-through systems. It is necessary to remember that somewhat higher concentrations of metaphosphate are required for corrosion control than for scale prevention, the actual requirement depending largely upon the severity of the conditions. In the case of recirculating systems the lower pH values are advantageous not only in changing the form of corrosive attack, but also in permitting use of sufficient metaphosphate residuals to overcome the most severe corrosion problem without danger of precipitating the rela-

tively insoluble calcium orthophosphates on heat-exchange surfaces.

Application of these principles in controlling corrosion has proved so effective that the deliberate addition of acid to recirculating waters in order to provide better control over corrosion has become quite common. Best results have been obtained by maintaining the pH value of the water at 6.5 and the metaphosphate residual between 10 and 20 ppm at all times.

Since the introduction of this low pH treatment, shortly before the last war, it has received the nickname, "low pH-high metaphosphate treatment," to distinguish it from the older Threshold Treatment at higher pH values which, in itself, is effective in overcoming the

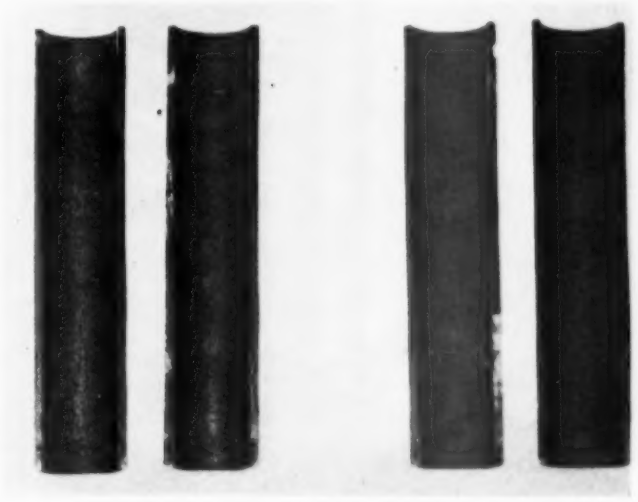

Fig. 3—Split sections of steel tubes removed from oil refinery cooling system employing low pH-high metaphosphate treatment after 6 (left) and 46 (right) weeks service. Weight loss determinations indicated corrosion rates prior to treatment between 200 and 300 milligrams per sq. decimeter per day. After treatment the rate of corrosion averaged 6.5 mg. with little or no evidence of pitting

less severe corrosion problems. The only disadvantage of the low-pH treatment is that it requires much closer control over both pH value and metaphosphate residuals than the older treatment while the chief advantage is the superior results that can be obtained in overcoming severe pitting.

Possibly one reason for the quick acceptance of the low pH treatment for corrosion control is the fact that the recommended pH range from 6.5 to 7.0 has been found to provide the optimum protection to the wood used in cooling towers. Acid treatment is an approved method of overcoming the chemical delignification of wood which is caused mainly by sodium carbonate in the recirculating water. It now appears that this pH range is also best to minimize the peculiar fungi attack on the wood that has become rather prevalent in the last few years, particularly since chemical delignification may contribute to the severity of this attack. While it is not usually necessary to reduce the pH value of the water below 7.5 to stop delignification, wood is naturally slightly acid and cooling tower manufacturers appear to prefer the lower values. It is fortunate that the pH values desired for protection of the metal surfaces in the system are within the optimum range for protection of the wood.

Chromate salts have been used quite effectively to control corrosion in open recirculating systems but in view of the fact that high concentrations are required the treatment is somewhat expensive. In order to conserve chemicals the tendency of the average operator was therefore to concentrate the makeup water to such an extent that a severe scale problem often ensued. This was largely overcome upon the introduction of the polymeric phosphates for scale prevention since very low residuals of phosphate would eliminate the formation of scale while the chromate would minimize corrosion. It was soon demonstrated, however, that slightly higher metaphosphate residuals in themselves were just as effective in controlling corrosion and the advent of the low pH-high metaphosphate treatment has made the use of supplementary inhibitors unnecessary although some plants are still using the older treatment of both metaphosphate and chromate while others still use chromate alone.

Control of Organic Growths

Cooling towers as well as spray ponds are efficient air washers so that contamination of the water with bacteria and algae is inevitable. Moreover, conditions in recirculating systems are such as to encourage prolific growths of micro-organisms of all types. All bacteria and bacterial slimes can encourage corrosion and several specific bacteria are primary agents of corrosion. Prolific growths of algae can cause calcium carbonate to precipitate where it would not otherwise do so, and dead algae as well as bacteria can act as a binder to plaster suspended matter and silt to heat transfer surfaces. In most cases chlorination, either continuous or intermittent, will prove to be most effective and most economical in preventing organic growths in cooling systems. Where process or other organic contamination precludes the use of chlorine immediate consideration should be given to the use of other disinfectants such as the chlorophenates or the quaternary ammonium compounds.

Many factors must be considered in connection with cooling water treatment. While treatment itself is not necessarily complicated, serious consideration should be given to all of the various factors before making any decision regarding the type of system or treatment to be used. Treatment of recirculating cooling waters may be compared somewhat to the treatment of boiler waters in that if the makeup water is good, internal treatment is usually the most convenient as well as the least expensive. If the makeup water is not so favorable only a combination of external pre-treatment and internal treatment will suffice.

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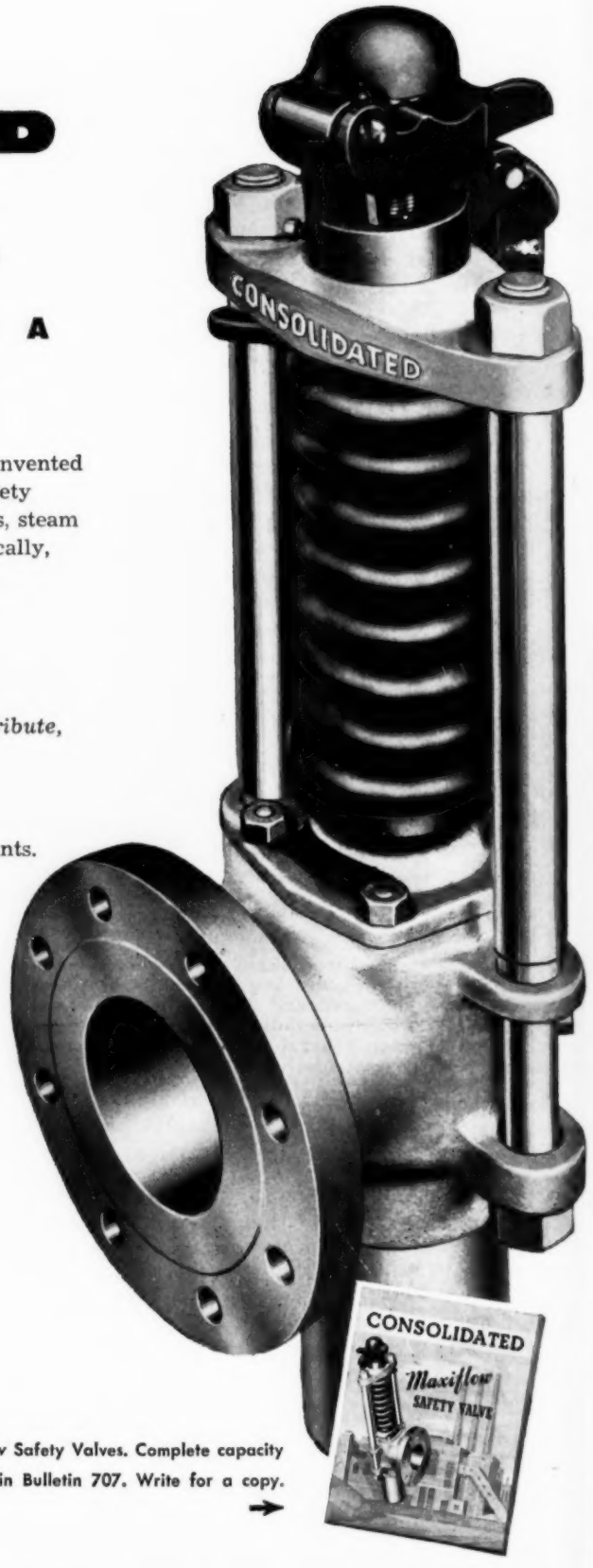

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Softening Temperatures of Residual Fuel Oil Ash

By T. WIDELL* and I. JUHÁSZ†

IT is known that vanadium and alkalis are often constituents of deposits formed on superheaters when firing some residual fuel oils. The melting point of V_2O_5 is usually at least 150 deg F higher than the surface temperature of the superheater, even in up-to-date power plants, and that of alkali sulfates is still higher. From this it would appear that formation of such deposits is a consequence of the softening temperature of the mixtures in the deposits being lower than that of their components.

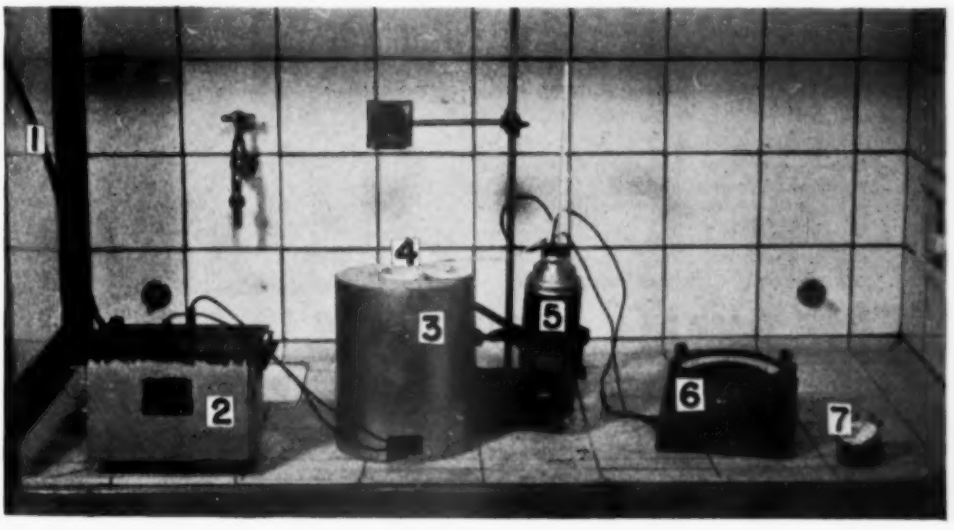
With the aim of ascertaining the softening temperatures of synthetic mixtures of vanadium pentoxide and sodium or potassium sulfates, a series of measurements was carried out in the laboratory of the Division of Heat Engineering at the Royal Institute of Technology in Stockholm.

TABLE 1—SOFTENING POINT OF SYNTHETIC MIXTURES OF SODIUM SULFATE AND VANADIUM PENTOXIDE

V_2O_5, %	Na_2SO_4, %	↑, °F	↓, °F
0	100	(1623)	...
10	90	1066	984
20	80	1066	964
30	70	1133	1088
40	60	1025	1005
50	50	1066	1048
60	40	1043	1005
70	30	1043	1005
80	20	1016	989
90	10	984	922
100	0	1205	1169

mixture allowed to cool. The crucible was then placed in the furnace which was heated slowly and the mv value read at least twice per minute. The rate of temperature increase employed was 35–70 deg F per minute at the softening point, and the cooling rate about 20 deg F per minute. Measurements were made at least twice with each mixture. The time-temperature curve exhibits discontinuities which represent phase changes. Additional visual observation showed that the discontinuity at the lowest temperature was also a change in the state of aggregation.

The measurements are given in Tables 1 and 2, two temperatures being shown for each mixture. The first



Apparatus used in laboratory study at Royal Institute of Technology

The experimental apparatus is shown in the accompanying photograph. Wire *1* is connected to an electrical outlet. The secondary current from transformer *2* heats the electric furnace *3* and the crucible *4* is made of platinum to avoid reactions between it and the test mixtures. Six grams of a synthetic mixture was placed in the crucible and the temperature of the mixture was measured with Pt-PtRh thermocouples. The junction of the thermocouple was left bare in the mixture to avoid errors caused by the insulating effect of the protective tube ordinarily used. Reference temperature was taken in a thermosbottle *5* and the thermoelectric voltage was measured with a millivoltmeter *6*. Measurements were taken in the following way:

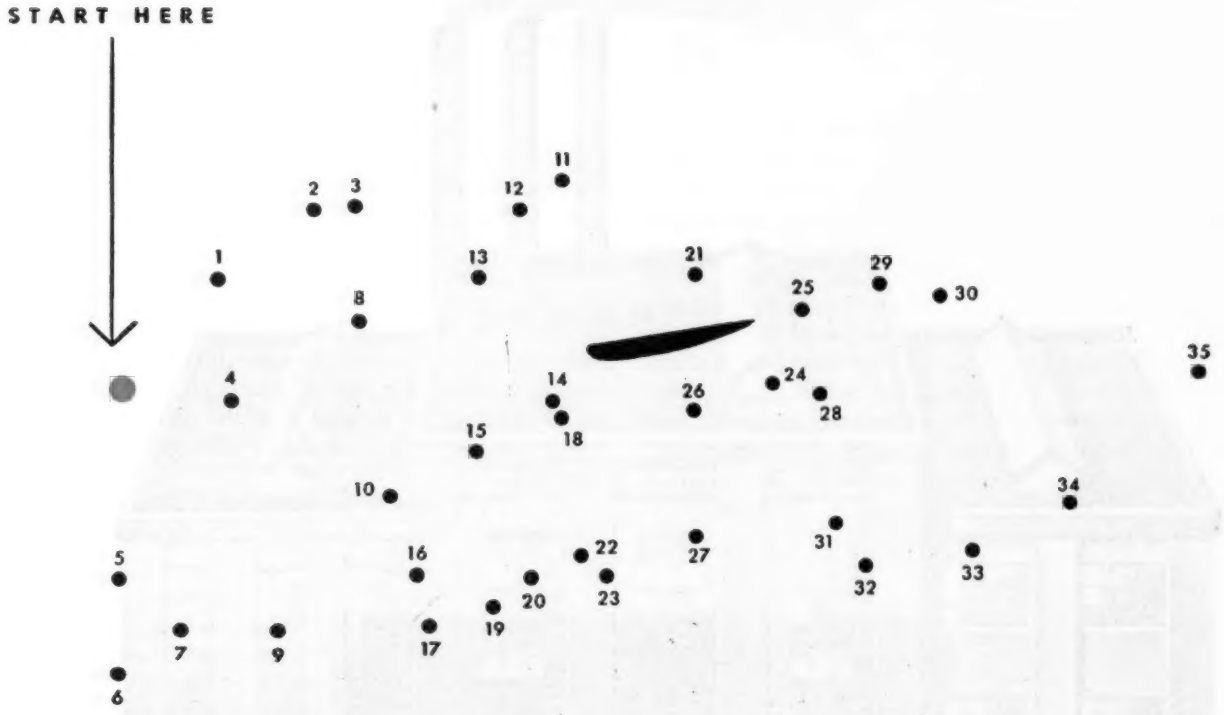
The mixture was heated over a gas flame, while being carefully watched to see that no white smoke appeared, as evidence of decomposition. The thermocouple was placed in the heated mixture and the crucible and the column refers to the softening point with rising temperature, the second to the softening point with falling temperature. The figures on pure alkali sulfates are taken from existing literature. As can be seen from Table 1, the softening point for the mixture of V_2O_5 and Na_2SO_4 is practically constant, and from 150 to 200 F lower than the melting point of the pure vanadium pentoxide. Table 2 shows that the softening point of mixtures of V_2O_5 and K_2SO_4 is 300 to 400 F lower than the melting point of pure V_2O_5.

TABLE 2—SOFTENING POINT OF SYNTHETIC MIXTURES OF POTASSIUM SULFATE AND VANADIUM PENTOXIDE

V_2O_5, %	K_2SO_4, %	↑, °F	↓, °F
0	100	(1969)	...
25	75	791	773
50	50	809	791
75	25	881	845
100	0	1205	1169

These lowered softening points may at least partly explain the various effects which reduce boiler availability in modern steam boilers fired with some residual fuel oils.

* Associate professor and head of Division of Heat Engineering I, Royal Institute of Technology, Stockholm.
† Consulting engineer and instructor in the Royal Institute of Technology, Stockholm. M. Inst. F.



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BOILER WATER CONDITIONING • COOLING WATER CONDITIONING • INDUSTRIAL WASTE TREATMENT

Dust Emission From Coal-Fired Boiler Furnaces*

By ELMER R. KAISER

Assistant Director of Research, Bituminous Coal Research, Inc.

A general theory of the behavior of small coal, ash and cinder particles in a boiler furnace is accompanied by a discussion of the basic factors affecting the emission of fly ash and cinders from stacks. These include coal size, type of firing equipment, gas velocities, turbulence, dust collection and dust reinjection.

IN the following, the term "fly ash" refers to particles of non-combustible solids carried by the furnace gases, in contrast with "cinder" which is used to designate hollow or porous particles of charred coal and coke carried by the gases. Fly ash and cinders constitute "dust." Smoke, as distinguished from dust, is the result of incomplete combustion of volatile matter, and usually consists of particles under one micron ($^1/_{25,400}$ in.). Soot is composed of agglomerated smoke particles.

The range of particle sizes here discussed, including the equivalents in microns, inches, and sieve sizes, is given in Table 1.

TABLE 1—EQUIVALENTS OF DUST SIZES

Microns	Inch	U. S. Sieve Series, Mesh, Openings per Inch
10	0.00039	Sub-
20	0.00079	sieve
30	0.00118	range
44	0.0017	325
74	0.0029	200
149	0.0059	100
250	0.0098	60
500	0.0197	35
840	0.0331	20
1000	0.0394	18
1410	0.0555	14

Behavior of Coal During Heating

In pulverizer and spreader firing, the small particles of bituminous coal in suspension are heated rapidly when exposed to the intense heat of the furnace. These

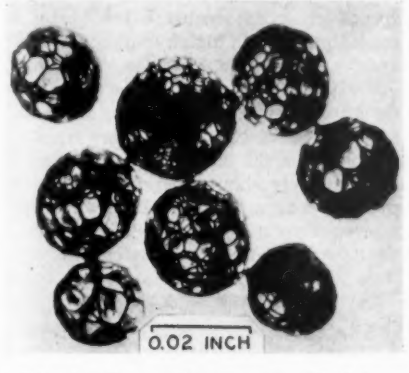


Fig. 1—Cenospheres magnified to show structure

particles soften and swell into multicellular bubbles of coke, known as "cenospheres." Cenospheres are new-born cinders, specimens of which are illustrated in Fig. 1.

Measurements reported by Sinnatt (1)[1] indicate that particles of bituminous coal increase in volume up to forty times shortly after entering a furnace at 1100 F or hotter. The average increase was eleven times the original volume. The density of the coal (1.3 to 1.7) would be expected to decrease correspondingly to 0.12 to 0.15 for average cenospheres, and possibly to 0.033 in extreme cases.

Cenospheres may be formed with the loss of not over one per cent of the volatile matter of the coal. The volatile matter comes off after the cenospheres are formed and burns in a flame surrounding the particle. When oxygen can penetrate the envelopes of burning gas, the thin windows of the cenospheres are consumed, opening the internal lattice structures to combustion. Many of the particles enter the tube banks of the boiler, where the combustion ceases before the carbon is entirely consumed. As is evident under the microscope, whole cenospheres and fragments of cenospheres constitute a substantial proportion of boiler dust.

Distribution of Ash in Coal

The ingredients of ash are disseminated throughout the structure of coal in varying degrees of dispersion. Much of the ash in coal may be thought of as having been finely divided, and intimately but not uniformly mixed with the vegetable matter from which coal was formed. The swelling of coal particles during cenosphere formation further subdivides and separates the ash into minute specks. As the cenospheres burn, numerous minute bits of ash are released.

Part of the ash that is released in the fuel bed is loose and powdery. Another type of ash consists of layers that remain fairly coherent after the combustible portion is burned away. Such pieces remain on the grate. An additional portion of the ash sinters as it is released and forms agglomerates or clinkers which are too dense and too heavy to float in the rising gases.

Carrying Power of Furnace Gases

Minute particles of coal and dust are easily transported in air because once lifted they settle out very slowly. The settling rate is an important and easily understood characteristic of a particle, but it has not received the attention it deserves. Known as "terminal velocity," it is the rate at which a particle will fall in a motionless fluid, and is usually measured in air at 70 F. It is equal to the velocity of an upward moving fluid that will suspend the particle at a fixed elevation. An upward velocity exceeding the terminal velocity of a particle will lift the particle in space.

The size, shape and density of a particle affect its terminal velocity. Likewise, the viscosity and upward velocity of the fluid, in this case a gas, determine how large and heavy a particle can be lifted from the grate or firing zone into the boiler passes.

What, then, are the actual upward velocities above a fuel bed and what size particles of coal, cenospheres and ash can be floated?

Consider the case of a spreader-stoker fuel bed with grate openings of 5 per cent of the grate area, and void areas in the ash and coal layer of 30 per cent. The upward velocities of the air through the grate and ash, and of the gases above the fuel bed, are given in Table 2 for three operating rates.

TABLE 2—VERTICAL GAS VELOCITIES IN SPREADER-STOKER-FIRED FURNACE

	Firing Rate, Lb Coal per Sq Ft per Hr:		
	20, Excess Air, 60%	30, Excess Air, 40%	40, Excess Air, 30%
	Ft per Min		
Entering grate, 70 F	71	93	115
Through grate	1420	1860	2300
Through ash, 400 F	384	500	620
Above bed, 2500 F	440	575	710

By comparing the actual upward velocities above the fuel bed (440 to 710 ft per min) in Table 2 with the terminal velocities of particles (2, 3) in Table 3, it will be found that particles of 250 microns and less are carried up by the gases at firing rates of 20 lb per sq ft per hr and more. Furthermore, even 500 and 840 micron particles are carried upward if their densities are low enough. At the 40-lb firing rate, the particles whose sizes are italicized in the table can fall to the grate, the others will rise.

From Tables 2 and 3, it may also be concluded that a coal particle of 600 microns and density 1.5 will fall toward the grate when fired horizontally into the furnace space by a spreader stoker while operating at the 30-lb rate. However, in the intense heat of the furnace, the particle will most likely be converted to a

[1] Numbers refer to references at the end of the paper.

* From a paper before the Air Pollution and Smoke Prevention Association of America at Roanoke, Va., May 8, 1951.

TABLE 3—APPROXIMATE TERMINAL VELOCITIES OF DUST IN BOILER FURNACES AT 2250 TO 2500 F

	Particle Diameter, Microns:						
	44	74	149	250	500	840	1100
	Sieve Size, Mesh:						
Particle Density	325	200	100	60	35	20	18
	Velocity, Ft per Min						
0.2	0.8	2.2	9	21	71	164	216
0.5	2.0	5.5	23	52	177	410	540
1.0	3.9	11	39	103	355	*820*	*1080*
1.5	5.9	17	67	154	532	*1230*	*1620*
2.0	7.8	21	78	206	710	*1640*	*2160*
2.5	9.7	28	98	257	*890*	*2050*	*2700*

cenosphere, possibly swelling to 5 times its former volume. Its new diameter will be 1000 microns, its new density will be 0.3 and its terminal velocity will decrease from 735 to 324 feet per minute. The transformed particle will stop falling and will rise rapidly with the gases.

Small particles of coal and ash on the grate may be trapped between or under larger pieces of coal and thus escape being blown into the furnace space. Likewise, small particles are relatively safe while in the zone of low gas velocity immediately adjacent to the surfaces of larger pieces.

Influence of the Firing Method

The factors of cenosphere and coke formation, gas velocity, terminal velocity of particles of fuel and ash, and the conditions for combustion in the furnace space vary widely with different methods of burning coal. Consequently, the dust losses from the boiler furnace are also closely related to the firing equipment in use. All of the dust does not escape out the chimney because boiler hoppers, dust traps and dust collectors of various types are widely used.

Pulverizer Firing

When coal is pulverized to 70 per cent minus 200 mesh (93 per cent minus 100 mesh), all of it is in the size range of dust. On burning in suspension, the powder is easily carried in the gases, especially in the form of cenospheres. The combustion is ordinarily quite complete, but less than half of the ash remains in the boiler furnace, and then only when agglomeration of fused particles or when adhesion to the furnace walls, bottom or tubes occurs. The dust carried through the boiler contains only about one to two per cent of the fuel value of the coal.

Cyclone Burner

The Cyclone burner (4) recently introduced for large boilers burns a minus $^1/_4$-in. coal held on a layer of slag by the centrifugal force of a vortex of air and combustion gases. The ash is consolidated in molten form and is tapped continuously from the furnace. Nevertheless, about 16 per cent of the extremely fine ash escapes with the gases and a small additional portion is lost by volatilization. The combustible content of the dust is negligible.

Industrial Spreader Stoker

A wide variety of coal sizes ranging up to about $1^1/_4$ in. is sprinkled over horizontal grates by spreader stokers, both mechanical and pneumatic, which are mounted on the front walls of boilers. During firing, the pieces of coal are dispersed and are acted upon individually by the gases. The smaller particles, ranging up to possibly $^1/_8$ in., depending on the operating rate, do not land on the grate but burn in suspension. The larger pieces are consumed on a thin fuel bed which occupies the full floor area of the furnace.

Air for combustion is supplied under the entire grate. When burning a $^3/_8 \times 0$-in. coal at a high rate, one-third of the ash may enter the tube bank, together with at least an equal amount of carbon (5). Ordinarily, 20 to 25 per cent of the ash is removed from the furnace by the gases (6). Barkley reports 20 to 40 per cent of the ash leaves the furnace (7).

Locomotive Spreader Firing

Steam locomotives have firing rates of up to 180 lb per hr per sq ft of grate, or at least three times the rates of industrial spreader-fired boilers. The upward gas velocities through the grates are correspondingly higher.

To sustain the higher rates, 4×2-in, coal is supplied to the stokers. Because of degradation of the coal sizes by the stoker screw, some minus $^3/_8$-in. coal is produced. At the higher rates, only the coarser coal reaches the fuel bed, while the fines are burned in suspension or are lost. Normal operating rates at low or medium running speeds are considerably below the maximum, but are still high by industrial standards.

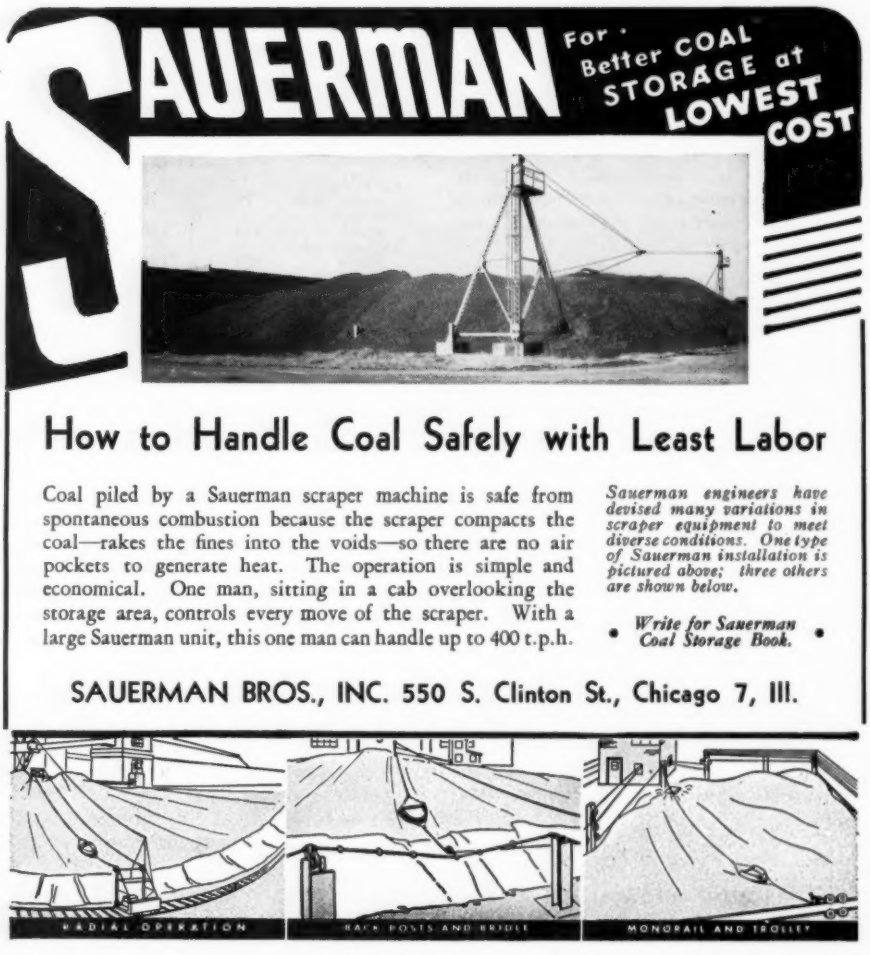
Progress has recently been made in reducing cinder and ash losses from locomotive stacks through the wider use of double-screened coal. Carbon losses increasing from about 5 per cent at the 50-lb rate have been determined (8) for a locomotive operating on a double-screened coal.

Traveling-Grate Stoker

Like the spreader stoker, the traveling grate utilizes the entire floor area of the furnace and thus has correspondingly low blast velocities through the fuel bed. The windbox is zoned to increase velocities in some areas of the grate and to decrease the air in others. Air is also supplied to the furnace space by overfire jets.

Because the fuel enters the furnace while on the grate, and because tempering with moisture is practiced, many of the fine particles are retained in the bed. Some of the ash is sintered in the fuel bed, but massive clinkers are not produced.

The amount of fly ash and cinder lost with the gases from this machine is relatively low. About 15 per cent (6) of the ash is carried up by the flue gas at normal operating rates.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UNDERFEED STOKER

The underfeed stoker is unique in first combining small pieces of coal into large pieces of coke before subjecting the fuel to combustion. The coke then burns in contact with air flowing at high velocity through channels between the pieces. Although these velocities are higher than experienced with other grates, the relative absence of small particles of fuel decreases the quantity of cinder.

The ash is largely fused into clinker because of the high temperatures. Dense beads of ash may be seen attached to the surface of the coke. Many particles that are blown out of the bed by the blast are redeposited in relatively inactive zones where they can combine by sintering.

The underfeed stoker has a good reputation for low dust losses, less than 15 per cent of the ash being lost with the flue gases (6), as a general rule. Barkley reports that 5 to 30 per cent of the ash in the coal leaves the furnace (7).

Size Distribution of Dust

Numerous analyses of dust from a variety of reliable sources were examined and averaged to provide a summary of the size distributions normally encountered. Table 4 is included for general information only. Dust from individual stokers can vary widely, depending on the rate of operation and numerous other factors. In general, the dust becomes coarser as the firing rate increases.

The 0–10 micron fraction is important because it is especially difficult to collect, even with high-efficiency centrifugal collectors. Particles between 10 and 100 microns are collected with various efficiencies, depending on the collectors. Even a simple dust trap can collect 90 per cent of the particles over 100 microns (9).

Combustion in the Furnace Space

The importance of furnace space in completing the combustion, whether the coal is burned in suspension or in beds, has been well recognized since the work of Kreisinger. Not only the hydrocarbon gases but also the particles of cinder can be burned under favorable conditions of time, temperature, turbulence and oxygen.

Small particles of coal and cenospheres can be burned in space when the turbulence brings enough oxygen rapidly to the particle surface (5, 10). The temperatures are ordinarily high enough in industrial furnaces, but turbulence may be insufficient. The turbulence should be intense enough to scrub off the film of nitrogen and carbon dioxide surrounding the particle and to thus hasten the diffusion of oxygen to the carbon. Ideally, turbulence should exist in all zones of the furnace space where suspended particles contain carbon.

To create turbulence, horizontal jets of air or steam are very effective, especially when located about 12 in. above the fuel bed, and possibly even lower. To provide turbulence over the entire grate area of a stoker, for example, the jet nozzles may be located in opposite furnace walls and spaced about 24 in. apart. By staggering or alternating the locations across the furnace, the parallel jets from opposite walls will be about 12 in. apart. As the jets of steam or air increase in diameter with distance from the nozzles, almost all of the gases leaving the fuel bed are mixed violently. More complete specifications for designing jet installations are available (11, 12).

TABLE 4—GENERAL SIZE DISTRIBUTION OF TOTAL DUST FROM BOILER GASES, PER CENT BY WEIGHT

Particle Size, Microns	Pulverizer Firing	Cyclone Furnace	Spreader Stoker	Traveling Grate	Underfeed Stoker		Steam Loco.
0–10	25	72	11		7	35	5
10–20	24	15	12	11	8	22	3
20–30	16	6	9		6	7	3
30–40	14	2	10		9	8	3
44–74	13		12	12	8	3	5
74–149	6	5	17	30	19	25	10
149 plus	2		29	47	43		71
	100	100	100	100	100	100	100
No. of analyses averaged	7	2	13	2	8*	1	11

* High-rate operation.

Dust Circuits of Spreader-Stoker-Fired Boilers—Three Systems in Use

The emission of dust from spreader stokers has received considerable attention in recent years (10, 13). Mechanical and electrical separators are available to reduce the emission below the legal limits. However, in practice the selection of the equipment is governed not only by municipal restrictions, but by space limitations near the boiler, cost of a collector installation, cost of dust disposal, recovery of heat from unburned carbon and other economic factors.

Boiler-plant operators have three principal alternatives for the operation of dust collectors with spreader-fired boilers, each of which can comply with dust regulations, but with different overall economies:

1. Without dust refiring. The dust trapped by the boiler passes and by the external dust collector is disposed of as refuse, or at least not refired in the boiler of origin.

2. Partial dust refiring. The dust from the boiler passes, being rich in carbon, is returned to the furnace, for example, by reinjection through nozzles, but the dust from the collectors is wasted.

3. Total dust refiring. All dust collected is returned to the furnace to recover fuel values and to dispose of the fine ash.

Methods of operating without dust collectors are practical, but they are not considered here.

A detailed study of overfire jets as applied to a spreader-fired boiler has been made and will be reported soon (14).

Importance of Returning Ash to Grate

It has often been assumed that ash from reinjected dust could not be redeposited on

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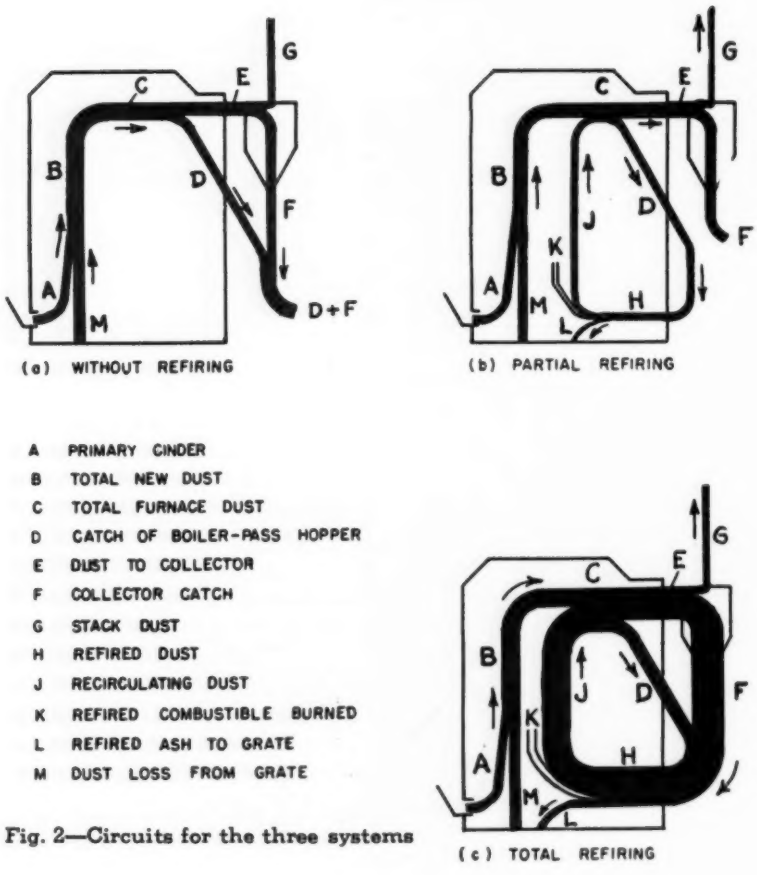


Fig. 2—Circuits for the three systems

the grate because the same velocities that lifted the dust originally would surely lift it on succeeding refirings (10). This assumption is true if the dust is not refired so as to give it an opportunity to land on the fuel bed. Fine dust can be held on the bed in particle form in two ways:

1. By being held or wedged under or between larger pieces of ash.
2. By lying adjacent to larger pieces and away from the high velocities of the air and gas streams in the fuel bed. The gas velocities are not uniform immediately above the bed. High velocity gases can issue only from the spaces between the pieces of coal or ash.

In the high temperatures at and near the top of the fuel bed, fine particles of ash are likely fused or sintered into heavier pieces of ash that will remain on the bed. The physical mechanism of ash release from fine particles and the agglomeration of reinjected ash in the fuel bed is in need of further research.

In a recent series of tests with $1^1/_4 \times 0$-in. coal on a spreader-fired railroad locomotive, 80 per cent of the cinder carryover was caught in a collector. The cinders were reinjected into the firebox at a low level in much the same manner as in industrial furnaces (17). About half of the reinjected cinders were burned. Of the cinders burned on refiring, "by far the greater part of these cinders burned on the bed thereby releasing their ash on the grate." In fact, the results of these tests showed that 43 per cent of the ash in the cinders was recovered in that way at a burning rate of between 45 and 50 lb per sq ft per hr.

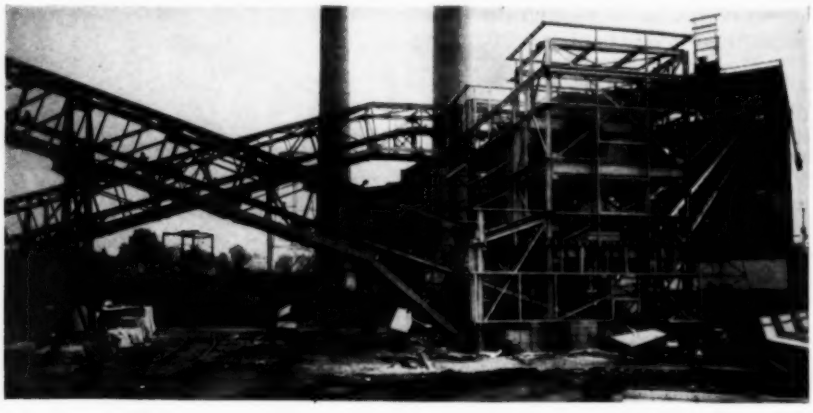
Were it not for the deposition of ash on the grate by reinjection of dust near the fuel bed, total refiring would cause all of the fly ash to leave the circuit via the stack. In that event, the dust loading throughout the system would increase until the rate of ash emission from the stack equalled the rate at which new ash entered the circuit.

To avoid concentrating the dust over a single lane of the grate or recirculating too much of it through a narrow portion of the first tube bank, the trend has been to increase the number of reinjection nozzles and to space them in the rear wall of the furnace. Reinjection nozzles have been installed in the side walls. As reinjection recirculates much of the dust, other means of refiring the dust may well be considered for spreader stokers.

Disposal of the dust by returning it to the furnace helps to burn out the carbon, to reduce the volume, to consolidate fly ash with the normal refuse from the grate, and to eliminate the special problems of handling a finely divided material.

Diagrams of Dust Flow

Fig. 2 illustrates the dust circuits for the three methods of dust disposal. The solid bands represent dust flowing in the circuits. The widths of the bands are in proportion to the hourly weights of dust. The dust is shown as originating from two sources, *A*, the fine particles in the coal



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feed, and M, the dust released from the fuel bed.

Without refiring, Fig. 2a, A and M are the only dust entering the boiler passes. The coarser dust D that is dropped into the boiler-pass hopper reduces the dust loading of the gases E to the collector. A portion of the finer and higher ash dust G escapes to the stack, but the major portion of the dust F is caught. Dusts D and E are not refired, but are wasted separately or with the furnace refuse.

With partial refiring, Fig. 2b, dust D is reinjected into the lower part of the furnace, a short distance above the fuel bed. When refired so as to project the dust H at a slight angle toward the grate, a minor portion of the ash L stays on the grate and some of the combustible K is burned out of the cinders both on the grate and, more likely, in the furnace space. The portion J that neither burns nor stays on the grate again leaves with the furnace gases.

The dust circuit with total refiring, Fig. 2c, shows considerably heavier dust loadings than with the other methods of disposal. It is necessary for the fly ash lost up the stack plus the fly ash deposited on the grate, to equal the new ash added at A and M. As only a minor fraction of the refired ash is deposited on the grate, and only part of the refired cinder is consumed during each cycle, equilibrium is maintained by an increased quantity being recycled. A dust collector of higher efficiency is obviously required to meet the limit of dust emission because of the higher dust flow to the collector. Nevertheless, there is an upper limit of collector efficiency with total refiring above which the recirculating load becomes excessively heavy, unless the deposition of the ash on the grate is increased proportionately with collection efficiency.

Hypothetical Case

Based on selected factors, the dust circuits of a hypothetical 45,000-lb spreader-stoker-fired boiler were evaluated and showed that to meet legal restrictions, the dust emission at the stack was limited to 0.85 lb per 1000 lb of flue gas at 50 per cent excess air.

When burning a coal containing 5 per cent of minus 20-mesh particles, a collector of 70 per cent efficiency was found satisfactory when the dust was not refired. A collector efficiency of 74 per cent was indicated at partial refiring, whereas a collector efficiency of 90 per cent was required for total refiring of dust.

To meet the 0.85-lb dust limit with total refiring, it was necessary to reinject 826 lb of dust per hour, to deposit 18 per cent of the refired ash on the grate and to consume 49 per cent of the reinjected carbon. The gain in steaming rate by refiring dust was estimated at 1510 lb an hour.

Whichever method is adopted in a given plant depends on economic factors as well as on the limits of acceptable dust emission from the stack.

Acknowledgments

During the preparation of the paper suggestions and comments on subject matter were gratefully received from Messrs. Harry C. Ballman, Elmer J. Boer, Richard B. Engdahl and Frank H. Westlake.

Appreciation is also expressed to P. A. Bletzacker and J. R. Garvey for advice on the manuscript.

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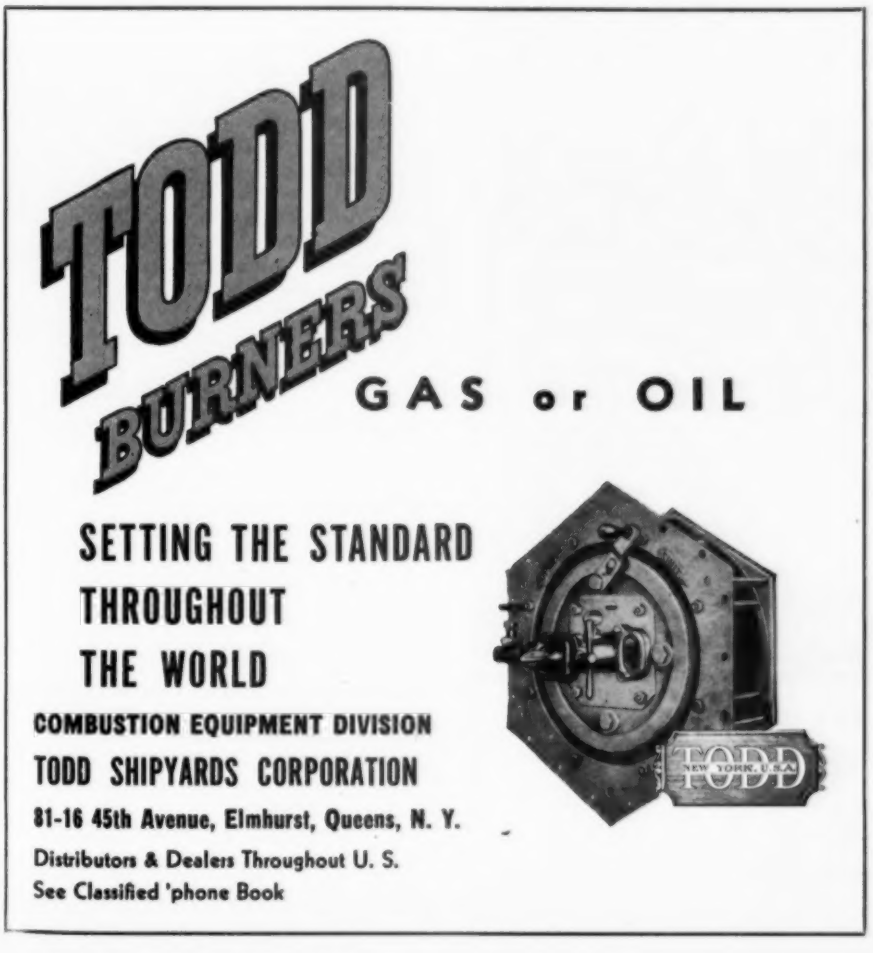

Gasoline From Coal in South Africa

Construction of a modern gasoline-from-coal synthesis plant will soon start in South Africa, according to announcement by The M. W. Kellogg Company, New York. The plant, largest industrial project to be undertaken in South Africa since the war, is being engineered and built for SASOL—South African Coal, Oil and Gas Corporation Ltd. It will be located adjacent to the Vaal River, near Coalbrook in the Orange Free State, about forty miles south of Johannesburg.

The project is an integrated plant which embraces the opening of virgin coal deposits to supply raw material. The Kellogg Synthol process is to be utilized. This differs materially from processes used in previous synthesis plants.

The new plant, the culmination of many years of planning by South African government and private interests, is primarily designed to produce liquid fuels—gasoline and diesel oil—in volume. While South Africa does not possess any major indigenous petroleum reserves, it does have tremendous deposits of coal available at low cost. Through use of this process, it is believed that these deposits can be utilized to make the country largely independent in the matter of liquid fuels.

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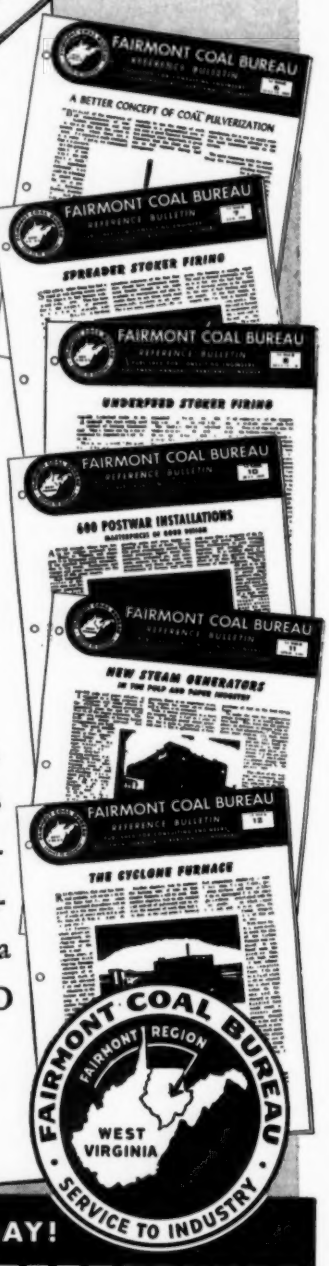

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Centralized Control to Feature ASME Semi-Annual Meeting

One of the high spots of the 1951 ASME Semi-Annual Meeting which is to be held at the Royal York Hotel, Toronto, Canada, on June 11–14 will be a symposium on centralized control and small gages. At this session, which is scheduled for Wednesday afternoon, June 13, the following papers will be presented:

"Modern Methods and Equipment for Control of Steam Generators" by P. S. Dickey of Bailey Meter Co.

"Electronic Combustion Control" by C. H. Smoot of Republic Flow Meters Co.

"Consideration in the Use of Smaller Instruments and Their Relation to Centralized Control" by T. W. Jenkins, Jr., of Leeds & Northrup Co.

"Centralized Control for Steam-Electric Generating Stations" by M. D. Engle and H. F. Hatfield of Pennsylvania Power & Light Co.

"Remote Operation Thru Centralized Control Rooms—A New Concept Developed on the A.G.&E. System" by T. T. Frankenberg of American Gas & Electric Service Co.

"Operating Experience with Centralized Control" by Ralph B. Gutekunst of Commonwealth Edison Co.

Other papers on controls and instruments will be presented on June 14, at which time E. Y. Stewart and J. H. Reynolds of General Electric Co. will discuss "Supervisory Instruments for Power Generating Equipment," and J. A. Tash of Duquesne Light Co. will have as his subject "Field Inspection of Boiler Tubes with Ultrasonic Reflectoscope."

On June 11 H. W. Iversen of the University of California will report on "Studies of Submergence Requirements of High-Specific-Speed Pumps" and W. H. Fraser of Worthington Pump & Machinery Corp. will discuss "Hydraulic Problems Encountered in the Intake Structures of Vertical Wet-Pit Pumps and Methods Leading to Their Solution."

Engineers in the steam power field may also be interested in a paper on June 12 by L. C. Andrews of the M. W. Kellogg Co. on "Piping Flexibility Analysis by Model Tests" and in a symposium on non-fuel uses of solid fuel at which the speakers will be H. J. Rose of Bituminous Coal Research, Inc., and R. C. Johnson of Anthracite Institute.

On Wednesday morning, June 13, W. C. Holton and R. B. Engdahl of Battelle Memorial Institute will have as their subject, "Methods of Reducing Dust Emission from a Spreader-Stoker-Fired Boiler Furnace."

"A Coal-Burning Gas Turbine" will be the topic of a paper by D. L. Mordell of McGill University on Thursday, June 14. Marine engineering will be the subject of another session that same day, at which the following papers will be presented:

"Marine Engineering in Canada" by A. C. M. Davy of the Canadian Dept. of National Defense.

"Geared-Turbine Repowering of Great Lakes Vessels" by B. E. Ericson of Pittsburgh Steamship Co. and F. H. Van Nest of General Electric Co.

"The Reboilering of the 'Homer D.

Williams'" by George J. Kirschner of Foster Wheeler Corp.

"Some Developments in Marine Boiler Design" by S. F. Mumford of Combustion Engineering—Superheater, Inc.

J. Calvin Brown, president of ASME, will preside and speak at the President's Luncheon on Monday, June 11. The Semi-annual Business Meeting of ASME will be held that afternoon, and a Junior Conference on the subject of "A Current Plan for Young Engineers', is scheduled in the evening. Carey H. Brown of Eastman Kodak Co. will lead the conference.

Duties of good citizenship will be emphasized in the Roy V. Wright Lecture which will be delivered at the Tuesday luncheon by C. J. Mackenzie, chairman of the National Research Council, Ottawa, Canada.

At the Banquet which is to be held on Wednesday evening, June 13, the speaker will be the Right Honorable C. D. Howe, minister of Department of Defense Production, Ottawa, Canada.

Inspection trips are scheduled to A. V. Roe Canada, Ltd., MacLean-Hunter Publishing Co., Christie Brown Biscuit Bakery, the Ontario Research Foundation and the University of Toronto Mechanical Building.

Wisconsin Power Conference

Highlights of the program for the Wisconsin Power Conference scheduled for June 6 to 8 at the Schroeder Hotel, Milwaukee are as follows:

Wednesday, June 6

"The Key to Personal Success," by Philip W. Swain, Editor of *Power*.

"Evaporating and Burning of Sulfite Liquor," by Nate Malcove, Technical Director, Northern Paper Mills.

"Mechanical and Electrical Fly Ash Eliminators," by Wiley W. Tomes, Cochrane Engineering Corp., Chicago.

"Operating Experience with Fly Ash Eliminators"—Symposium.

Thursday, June 7

"Industrial Boiler Plants," by C. E. Miller, Manager, Stoker Department, Combustion Engineering-Superheater, Inc., New York.

"The Cyclone Furnace," by R. K. Allen, Supervising Staff Engineer, Babcock & Wilcox Co., New York.

"Electrical Switchgear, Transformers and Motors for Industrial Plants," speakers from Westinghouse Electric Corp. and General Electric Co.

Friday, June 8

"The Role Played by Anti-Foams in Preventing Foaming and Improving Steam Quality," by Charles Bodach, Research Chemist, Dearborn Chemical Co., Chicago.

"Pumps for 1951," by O. M. Kristy, Centrifugal Pump Department, Allis-Chalmers Mfg. Co., Milwaukee.

"Power Plant Records," by G. A. Mierendorf, Chief Engineer of Power Plant, A. O. Smith Corp., Milwaukee.

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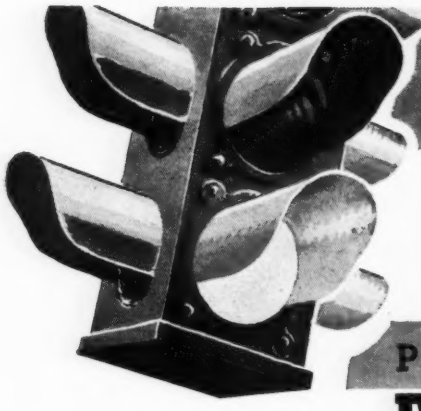

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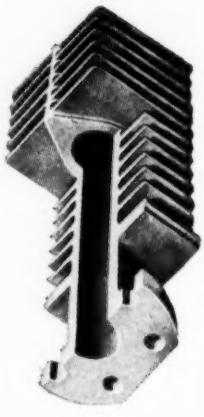

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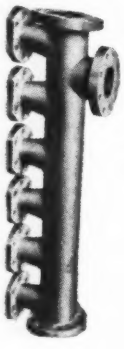

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Relationship of Station Cost to Unit Size

With the development of integrated power systems and high-capacity interconnections along with vast growth in electrical load, larger generating units have become more attractive. This was the main thesis of a paper entitled "The Effect of Unit Size on Steam-Electric Generating Station Design" which was prepared by J. B. McClure and A. G. Mellor of the General Electric Co. for presentation at the AIEE North Eastern District Meeting held in Syracuse, N. Y., on May 2-4. Larger units make it possible to take advantage of lower investment per kilowatt, higher efficiency, and lower operating costs.

By considering some of the major items of station equipment it is possible to observe trends in plant cost for different size units. Turbine-generators of 3600 rpm having capabilities ranging from 40,000 to 160,000 kw and steam conditions of 1250 psig, 950 F, cost materially less per kilowatt as unit size is increased. For higher steam conditions and for reheat machines, the effect of increasing size is even more pronounced. This is because almost the same amount of material is subject to higher temperatures and pressures regardless of the capacity of the turbine. For this reason it is easier to justify using high temperature and reheat in larger turbine-generator units than in small machines. Assuming one boiler per turbine, the curves of cost against size for boilers have similar characteristics to those for turbine-generators. Furthermore, with larger boiler-turbine-generator sets building space per kilowatt of generating capacity decreases and may result in worthwhile savings.

The unit system of station design has been generally accepted for larger generating units. The reliability of modern boilers, turbine-generators and transformers has made it possible to eliminate all steam and electrical connections (at generator voltage) between units. This simplification results in savings which become even more important with increasing unit size. Other factors relate to the impracticability of distributing power at generator voltage with the larger units, thus elminating need for generator busses, and the desirability of the simplicity of the unit system for steam headers when reheat is employed.

Among the conclusions of the authors were these:

1. Substantial savings in investment cost per kilowatt of generating capacity can be realized by the use of larger generating units. (The paper considered the range of 40,000 to 160,000 kw.)
2. With increasing unit size there is a direct and proportional reduction in operating cost per kilowatt-hour generated.
3. Although increased size of itself with fixed steam conditions does not appreciably reduce heat rate, the extra cost of higher steam conditions and of the reheat cycle can be more easily justified in larger units.
4. It is advisable to design large generating stations on the unit system, wherever possible, thus avoiding steam and electrical interconnections and the need for switchgear at generator voltage.

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Consolidated Edison Expansion

At a meeting of the A.S.M.E. Metropolitan Section on April 25, Gordon R. Milne and H. Knecht of the Consolidated Edison Company of New York discussed design considerations for generating units that are to be placed in service in the next two years by that system. These include a 66,000-kw topping unit for the Hudson Avenue Station (Brooklyn), which is to go into operation this summer, two 137,000-kw units at East River Station, scheduled for operation in September and December of this year, two 180,000-kw reheat units for the new Astoria Station, operation of the first of which is planned for December 1952, and a 180,000-kw reheat unit at East River which is to go into service by the end of 1953. Capacities of these units are expressed as gross maximum capability.

Mr. Milne pointed out some of the difficulties in finding suitable steam-plant sites in the vicinity of New York City. Because of transmission costs it is not feasible to locate very far from the city. Both the north and south shores of Long Island are largely residential and offer few satisfactory sites. Other locations are ruled out because of restrictions on stack height resulting from close proximity to airports. Two sites for future plants were mentioned, one along the Arthur Kill on Staten Island and the other at the Hunts Point gas plant. In addition, there remains some room for expansion of the Hudson Avenue, East River and Sherman Creek Stations.

A topping unit soon to go into service at Hudson Avenue was chosen because there is a deficiency of steam capacity resulting from the abandonment of boilers at the near-by Gold Street Station. The new steam generating unit will have a capacity of 1,300,000 lb per hr at 1500 psig, 1050 F, and the topping turbine will exhaust to low-pressure units operating at 275 psig and 400 psig. When maximum capacity is needed, the 275-psig machines will be operated. At other times the exhaust from the topping turbine will go to a 400-psig header.

The two units which are to go into service this year at the East River Station will operate at 1500 psig, 1000 F. Each boiler will have a nominal capacity of 1,100,000 lb of steam per hour. High-pressure feedwater heaters will be installed in parallel sets, the second group of which will be used to heat feedwater from the existing station. Precipitators having an efficiency of 95 per cent will be used.

The third unit for East River, which is scheduled for operation at the end of 1953, will have throttle conditions of 1800 psig and 1000/1000 F steam temperature. Steam will be supplied by a dual-circulation boiler.

Astoria will be the first new station to be placed in service by Consolidated Edison since the East River Station was put into operation in November 1926. The reheat turbines will be of the cross-compound type with both shafts turning at 3600 rpm. Throttle conditions have been established at 1800 psig, 1000/1000 F. The boilers, which will have a throttle flow of 1,200,000 lb of steam per hour, are being designed for pressurized operation. No forced-draft fans will be installed.

REFIRE HIGH CARBON DUST
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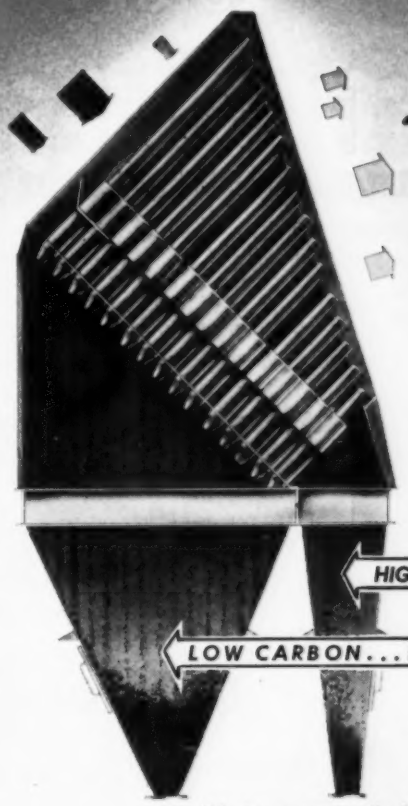

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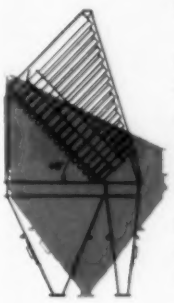
Fly-ash from spreader stoker-fired units, consisting of up to 40% high carbon particles, can effect considerable savings when re-injected. It is necessary to effect separation, however, since the non-combustible smaller particles remaining in the system increase in concentration, causing erosion and possible poor combustion due to spotting.



Space requirements for the decantation design are not as great in area and only slightly higher than a standard tubular . . . and, collection efficiency is high. Superimposed sketch shows comparative size.

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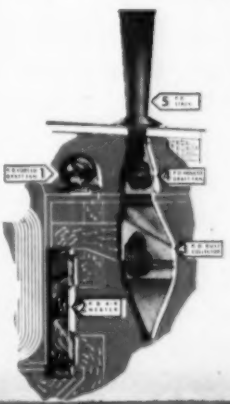

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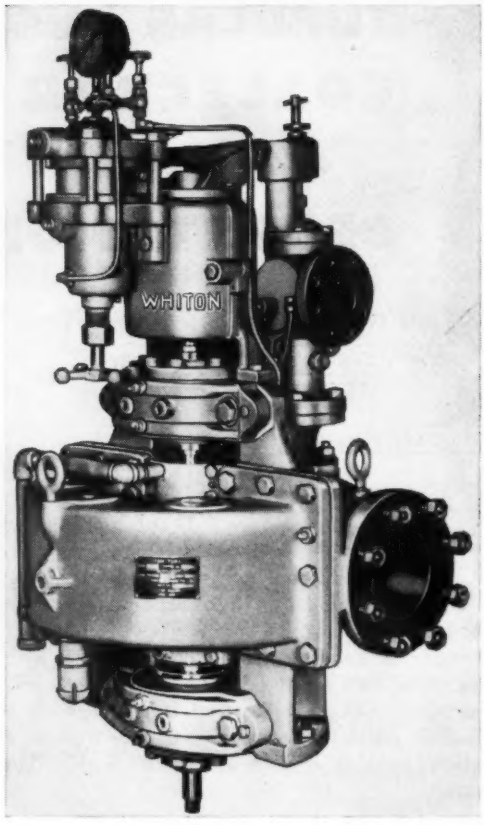

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Research in Coal Burning

At the Annual Meeting of Bituminous Coal Research at Columbus, Ohio, on March 7, **Julian E. Tobey,** president of Appalachian Coals, Inc., outlined some of the current research that is being carried on with a view toward improving coal's position. Many of these projects are being conducted by BCR in cooperation with other industries or individual corporations and include marine smoke abatement, reduction of fly ash from spreader stokers, automatic steam generators, gas producers, block heating, etc. The work involves collaboration with the U. S. Bureau of Mines, the University of Illinois and Carnegie Institute of Technology.

Overfire Jets to Reduce Marine Smoke

There are three to four hundred large bulk carriers on the Great Lakes, the majority of which burn coal. About two-thirds have Scotch boilers and the other third water-tube boilers. The black plume of smoke from the stacks is a common sight, hence an active program of smoke abatement has been undertaken in which the Lake Carriers Association, the Coal Producers Committee for Smoke Abatement and BCR are cooperating. Tests are being conducted to develop a system of overfire jets for use with both types of boilers and aimed to meet the smoke regulations in the port cities, as well as along the Detroit River and at the Soo.

For the railway field, at Battelle Memorial Institute, work is being carried on toward development of a method of collecting cinders from the combustion gases of steam locomotives and reburning them. The first part of this problem has been solved by the design of a collector of 85 per cent efficiency that will fit into the front end of a locomotive. However, the second part of the problem is not so easy, for merely blowing the cinders back into the firebox burns only part of them, with still a high percentage being lost out the stack. The latest thought is to return the larger cinders directly to the firebox and pulverize the finer cinders so that they can be burned in suspension.

Also, eighteen organizations and companies are sponsoring a survey of railroad electrification for which Battelle is doing the work.

At the General Motors plant in Elyria, Ohio, a spreader-stoker-fired boiler having a chain grate is being subjected to tests with a wide variety of coals burned with different arrangements of overfire jets. The conclusions so far are that jets located 18 to 28 in. above the grates are very effective in reducing the material blown out of the furnace.

While these tests proved that the jets will eliminate much of the fly ash from the gases, the problem of air pollution cannot be solved completely in this manner. In many spreader-stoker installations operating within city limits it will still be necessary to have collectors. However, the use of jets and the recirculation of cinders to the firebox will aid the efficiency. Other studies by Battelle indicate that the configuration of the boiler, the baffles, and other factors in-

fluence the amount of dust emission. Use of double-screened coal reduces the amount of cinder loss.

Dust Collector Studies

Another phase of the dust collector work has been the testing of several types of collectors in an effort to find one or more designs that will satisfy plants requiring a reduction of 50 to 60 per cent in the dust emitted without installing induced-draft fans or moving the boilers, as there is often only a limited space behind boilers for the installation of dust collectors. The Battelle laboratory has developed a design of louver-type collector that resembles a venetian blind. In this design the gases escape between the blades of the collector while the dust particles travel down over the surface to a point of removal.

Small Coal-fired Automatic Steam Generating Unit

BCR has undertaken the development of a small automatically controlled steam generating unit that will burn coal. This will consist of a fire-tube boiler equipped with a pneumatic spreader stoker, a traveling grate, cinder collector, re-injection system and automatic ash removal. The unit is now being assembled at Battelle and is expected to be ready for firing some time this coming summer.

New Gas-Producer Types

Also on the BCR program is development of a new gas producer. This study is under sponsorship of a group consisting of diesel engine builders, glass manufacturers, gas turbine builders and the bituminous coal industry. Three kinds of gas producers are being investigated. One of these is of the cross-feed type in which the fuel enters at the top with ashes discharged at the bottom; the blast enters from one side and the gas is taken off from the opposite side.

The second type is a combination producer, first investigated in Germany, and employing two or more shafts. While air and steam are passing upward in one shaft, the products from the first shaft are flowing downward in the second. Every few minutes the process is reversed.

The third, which was invented by a member of BCR staff, is of the continuous type in which the coal is converted into coke and the latter then gasified.

Block Heating

The block heating program is aimed at extending the markets for bituminous coal. In most cities individual heating plants are found in office buildings, stores, theaters, etc., some of which burn competitive fuels. This involves numerous firemen and a multiplicity of small chimneys, coal bins, ash piles and places for coal delivery. With block heating all these functions would be centered in one or two well-managed plants located within the block. This, of course, is not to be confused with district heating, which is on a larger scale and utilizes distribution lines under the streets.

In the field of gasification and carbonization BCR is continuing to support the work of the coal research laboratory of Carnegie Institute of Technology.

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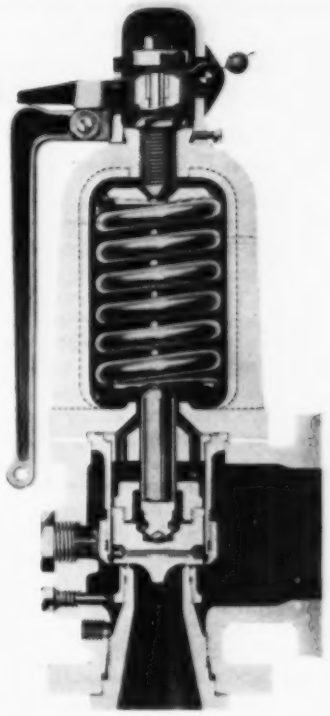

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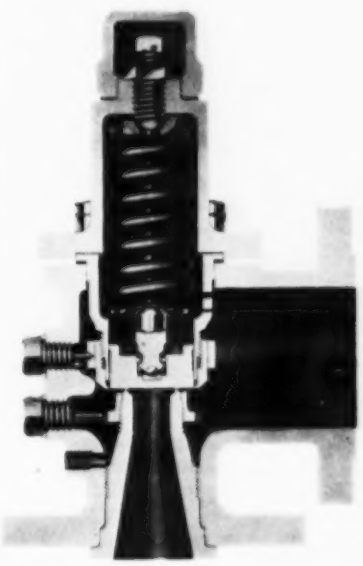

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Cast Iron Valves with semi-nozzle construction available for 400 PSI—100 F., or 250 PSI—450 F.

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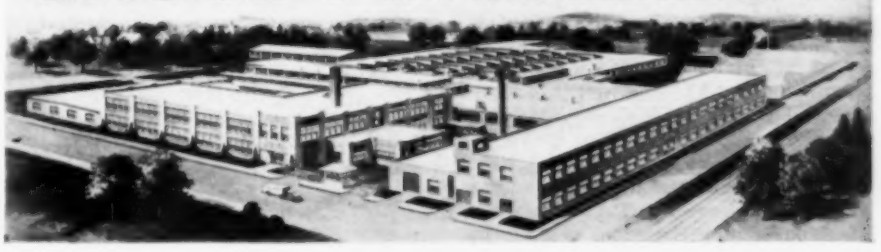

REVIEW OF NEW BOOKS

Any of the books here reviewed may be secured through Combustion Publishing Company, Inc., 200 Madison Ave., N. Y.

Steam Turbines Third Edition

By Edwin F. Church, Jr.

This text is intended for an introductory course in turbine design that may be given to senior mechanical engineering students or to those in the early stages of graduate study. Through the cooperation of American turbine manufacturers the book is well illustrated with many detail views of turbine construction and with numerous charts, curves and diagrams. There are extensive references to engineering literature and these are arranged conveniently by chapter headings.

The organization of the text proceeds from a consideration of turbine types and characteristics to a discussion of turbine cycles and nozzle proportions, with much of the emphasis on the thermodynamic theory that is involved. Three chapters are devoted to impulse and reaction blading, after which the effects of use, capacity, speed, and steam conditions on the arrangements of turbine elements are taken up. Among the other major topics covered are vibrations, considerations of aerodynamics and supersonic flow, structural elements and stresses, losses, efficiency, performance, and methods of turbine governing. A final chapter on design includes worked-out problems for designing a pressure-stage impulse turbine, for making preliminary calculations of final stages, and for designing a velocity-stage impulse turbine.

This revision is the Third Edition of the text which contains 531 pages and sells for $6.

Thermodynamics Second Edition

By George A. Hawkins

This text is intended for use in a two-semester undergraduate course in engineering thermodynamics. In the Second Edition much new material has been added and many chapters have been rewritten.

The author has attempted to provide a well-balanced treatment of the subject. To this end, fundamentals are presented first so that the student is able to master them and analyze an actual thermodynamic system by first visualizing an ideal system. Many references to authoritative engineering works are included at the end of each chapter, and the theoretical presentations are supplemented by practical examples indicative of actual engineering practice. Care has been taken throughout the text to insure the correct use of units.

Among the chapters are the following: Fundamental Concepts, The First Law of Thermodynamics, Equations of State for Real Gases, The Second Law of Thermodynamics and the Carnot Cycle, Mixtures of Ideal Gases and Vapors, Combustion, Ideal Cycles of Internal Combustion Engines, Vapor Cycles, Mechanical Refrigeration, General Thermodynamic Equations, and Introduction to Heat Transfer. An appendix includes abridged steam and air tables, tabulations of saturated sulfur dioxide, carbon dioxide and ammonia, a small Mollier chart and a psychrometric chart.

The text contains 563 pages and sells for $6.50.

Principles of Engineering Economy

By Eugene L. Grant

The Third Edition of this well-known engineering text continues the practice of stressing the question, "Will it pay?" in considering economic alternatives of technical projects. Although the general plan of organization has been maintained and places major emphasis on techniques for economy studies, more than two-thirds of the book has been rewritten.

New material has been added which discusses the treatment of prospective price changes, something which assumes considerable importance in engineering planning of the present. The chapter on theoretical aspects of replacement economy has been revised in accordance with an approach developed by George Terborgh of the Machinery and Allied Products Institute. New chapters have been added entitled "The Relationship of Income Taxes to Economy Studies" and "Further Examples of Economy Studies in Manufacturing Industries and Public Utilities."

There are many new problems, bringing the total to 400. Of these about 30 per cent have answers, making the text useful for self study.

Composed of 623 pages the book sells for $5.

Colloidal Dispersions

By Earl K. Fischer

This book has been read by a non-specialist in the field as a source of information. Engineering problems connected with the complex system of liquid solvents, dissolved and ionized salts, partially dissolved gases, finely divided insoluble matter with a suspected tendency to flocculate, adsorption, perhaps preferential of the solute, and evaporation of the solvent gave rise to the interest and desire for information.

Although the author has in mind the commercial fields of dyes, pigments and paints, his exposition of the known controlling factors and his collection of possible explanations for the observed properties is extremely helpful even to the interested non-specialist. Phenomena of the type described undoubtedly play a part in the process of vapor formation and vapor-liquid separation in steam generating units. The exposition is not only clear but the presentation is more than sufficiently interesting to hold the attention of the reader.

This book can be recommended for reading by non-specialists for informative reading with an assurance that their interest will be held. To those non-specialists with related problems the book will be most helpful. To the specialist the book provides a pleasant, helpful digest and summary adequately referenced to other sources for facts, methods and opinions.

The book has 387 pages and sells for $7.50.

Electrical Refresher for Professional Engineers License Examination

By John D. Constance

This paper-bound volume is a companion to "Refresher Notes for Professional Engineers License Examination" by the same author, both of which are based on review courses given in New York City. Subject matter includes electrical equipment, generators and motors, transmission and distribution of electrical energy, and electrical control. Solutions are given for 158 problems selected from past examinations. An index to the problems adds to the usefulness of the volume.

Sized $8\frac{1}{2} \times 11$ in., the book has 100 pages and sells for $2.

The Practical Engineer Pocket Book 1951

Edited by N. P. W. Moore

This British publication is a miniature handbook devoted primarily to mechanical engineering subjects. The units and terminology are those commonly used by British engineers, and commercial references are to products of English manufacturers.

Among the subjects covered are friction and power transmission, pyrometry, metallurgy, steam generation, steam turbines, condensers, gas turbines, locomotive practice, gas and oil engines, air compressors, hydraulics, machine tools and unified screw threads. Three brief technical dictionaries, German-English, French-English and Spanish-English, are included.

The book is pocket size, $3\frac{1}{2} \times 5\frac{1}{2}$ in., contains 744 pages, and sells for $3.

Nature, Occurrence, and Effects of Sigma Phase

This Symposium, consisting of 11 papers and discussions available in printed form, was presented at the 1950 Annual Meeting of the American Society for Testing Ma-

terials under the title "Effect of Sigma Phase on the High Temperature Properties of Metals," and was sponsored by the Joint ASTM-ASME Committee on the Effect of Temperatures on the Properties of Metals.

In his introduction, F. B. Foley, states: "There is perhaps no single phenomenon connected with the metallography of the corrosion- and heat-resistant iron-chromium and iron-chromium-nickel alloys that has excited more interest on the part of investigators during the past five years than the sigma phase. The studies, as shown by the papers presented, have brought into play all the methods available to the physicist and metallurgist aimed at determining what it is, under what conditions of composition, temperature and time it may form, how it forms and decomposes, how its presence may be detected and what its effects on the physical, chemical, and mechanical properties of the metal may be."

The papers, with their authors, are as follows:

"Identification and Mode of Formation and Re-Solution of Sigma Phase in Austenitic Chromium-Nickel Steels," by E. J. Dulis and G. V. Smith, U. S. Steel Corp.

"Sigma Phase in Several Cast Austenitic Steels," by V. T. Malcolm and S. Low, Chapman Valve Manufacturing Co.

"X-ray Study of the Sigma Phase in Various Alloy Systems," by Pol Duwez and S. R. Baen, California Institute of Technology

"Sigma Phase in Chromium-Molybdenum Alloys with Iron or Nickel," by J. W. Putman, N. J. Grant and D. S. Bloom, Massachusetts Institute of Technology

"The Tetragonality of the Sigma Phase in the Iron-Chromium System," by L. Menezes, J. K. Roros, and T. A. Read, Columbia University

"The Formation of Sigma Phase in 17 per cent Chromium Steel," by J. J. Heger, Carnegie-Illinois Steel Corp.

"Sigma Phase and Other Effects of Prolonged Heating at Elevated Temperatures on 25 per cent Chromium–20 per cent Nickel Steel," by G. N. Emmanuel, Babcock & Wilcox Tube Co.

"The Occurrence of the Sigma Phase and Its Effect on Certain Properties of Cast Fe-Ni-Cr Alloys," by J. H. Jackson, Battelle Memorial Institute

"The Formation of Sigma and Its Influence on the Behavior of Stabilized 18 per cent Chromium–8 per cent Nickel Steels in Concentrated Nitric Acid," by R. S. Stewart and S. F. Urban, National Lead Co.

"Some Notes on the Structure and Impact Resistance of Columbium-Bearing 18–8 Steels After Exposure to Elevated Temperatures," by W. O. Binder, Union Carbide & Carbon Research Laboratories

"Observations of the Effect of Sigma on the Mechanical Properties of Columbium—Stabilized Weldments in Austenitic Stainless Steels," by F. W. Schmitz and M. A. Scheil, A. O. Smith Corp.

This 188-page, profusely illustrated symposium, with paper cover, is priced at $2.50.

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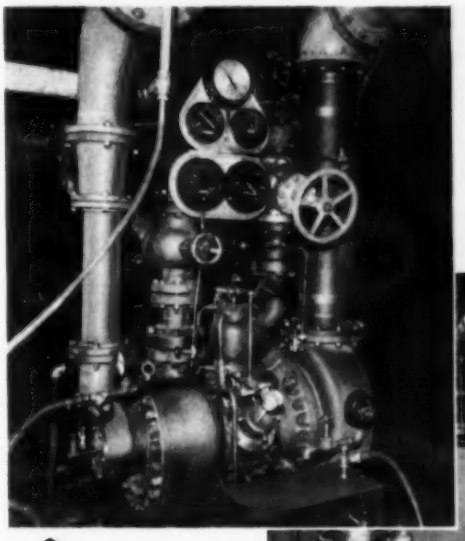
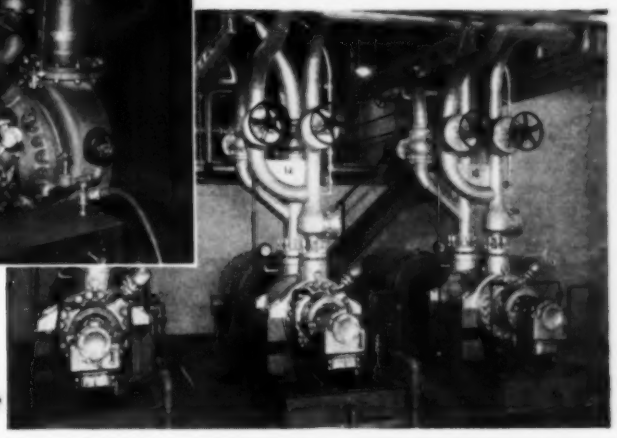


Pacific Steam Turbopump



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	4 Pumps	350,000	300	1060
	4 Pumps	455,000	336	1225
IBF CENTRIFUGAL PUMPS	3 Pumps	425,000	310	1825
	3 Pumps	495,000	306	1619
	6 Pumps	405,000	305	1750
	6 Pumps	405,000	305	1750
	3 Pumps	450,000	310	1825
	6 Pumps	550,000	334	2200
JBF CENTRIFUGAL PUMPS	2 Pumps	163,600	260	490
	1 Pump	117,500	250	775
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Atomic Energy Services

The Kellex Corporation, one of the first firms to enter the atomic energy field, has released an 18-page booklet, "Engineering New Fields," which describes its facilities and tells of the background of the Company. Mention is made of the work in which the organization has been engaged for the Atomic Energy Commission and the Armed Services and of its services to industry.

Cavitation Research

A 20-page bulletin, "Accelerated Cavitation Research," which describes cavitation-pitting tests has been released by Allis-Chalmers Manufacturing Co. The tests described were conducted to solve some of the phenomena of cavitation and to determine the relative resistance to pitting of recently developed materials and techniques for applying these materials.

Coal Handling Equipment

Bulletin No. 103 prepared by The C. O. Bartlett & Snow Co. describes coal handling practice for central power stations. Attractively illustrated with representative photographs of recent installations, the 20-page release also shows individual units of equipment and diagrammatic sketches, some with typical dimensions. Some of the topics discussed in the text include weighing, sampling, magnetic separation, skip hoists, crushers and breakers, yard storage and reclaiming, and distributing coal to the bunkers.

Combustion Controls

A 12-page bulletin prepared by the Cleveland Fuel Equipment Co. includes descriptive information, specifications and photographs of electric damper controls and gages. There is also a description of a new master regulator known as the Model SC-B steam control.

Condenser Tubes

"Life Extension for Condenser Tubes" is the title of a comprehensive and attractively illustrated 32-page bulletin prepared by Revere Copper and Brass Inc. Among the subjects covered are preventive metallurgy to increase tube life, protective films against corrosion, development work in tube alloys, quality controls in tube mills, composition and general recommendations for condenser tubes, condenser plates and support sheets and estimating data.

Dust Collectors

The latest design of mechanical dust precipitators is described in a 12-page bulletin, No. 1728, prepared by the American Blower Corp. Selection data and typical arrangements are provided for the Series 342 precipitator. Also included are dimensions and physical data, general details of subassembly construction and a description of factory-built package units.

Electronic Pressure Indicator

A six-page bulletin made available by Mogens Bang & Co., representatives of Danish manufacturers, describes an electronic pressure indicator for the measurement of static and rapidly alternating forces, pressures, distances and vibrations. Mentioned in the bulletin are applications, examples of measurements, principle of operation, and specifications.

Expansion Joints

Bulletin 351 issued by Zallea Brothers describes the complete line of Zallea expansion joints and flexible couplings. It gives sizes, dimensions, suggested applications and other technical data on a variety of joints from small flexible connectors for use on diesel exhaust lines to 30-ft diameter self-equalizing joints for use in wind tunnels.

Fire Brick

A 4-page illustrated folder prepared by Johns-Manville and entitled "JM-3000 Insulating Fire Brick" presents the economic advantages, industrial applications and refractory properties of this product, said to be the first insulating firebrick for sustained use at 3000 F. Information is also presented on other types of insulating brick.

Piping Pointers

Crane Co. has announced a new edition of its Piping Pointers manual, a 36-page bulletin which covers the fundamentals of sound piping practices in easily understood nontechnical language. Besides discussing the various types of valve designs and how each should be used, it illustrates and names more than 80 kinds of fittings. Many features relating to practical operation are included, together with a separate valve-selection guide.

Pipe-Line Filters

An 8-page bulletin prepared by the Dollinger Corp. describes Staynew pipeline filters which may be used to remove dirt and pipe scale from compressed air lines, to filter corrosive gases at high pressures or temperatures and to protect vacuum pumps by removing foreign matter. Installation views are shown of the new Series 600 filters which are built for pressures up to 6000 psi.

Speed Control

An attractive 12-page bulletin, No. G-509, describing the basic operating principle of Reeves variable speed drives and containing representative rating tables and dimension drawings, is being offered by the Reeves Pulley Co. Capacities range from $\frac{1}{4}$ to 87 hp with stepless speed changes within ratios from 2:1 to 16:1. The bulletin covers three types of variable speed units and mentions manual and automatic controls that may be used with them.

Steel Flooring

A 16-page catalog describing various types of open steel flooring and armoring is available from the Machinery Division of Dravo Corp., distributors for the Tri-Lok Co. The catalog discusses different types of open steel flooring and safety treads. It contains specification data, safe load tables, installation methods, and other pertinent information.

Soot Blowers

The Vulcomatic E-4 rotary soot blower head is described and illustrated in a 4-page bulletin issued by the Vulcan Soot Blower Division of Continental Foundry & Machine Co. Provisions for maintenance are mentioned.

Watthour Meters

A 40-page "Manual of Watthour Meters" which comprehensively covers the fundamentals of alternating-current metering has been prepared by the General Electric Company's Meter and Instrument Divisions. Fully illustrated with charts, diagrams and photos, the brochure shows how electric energy is measured; describes the operating principles of watthour meters; and explains the techniques involved in the use, testing and maintenance of meters.

Water Treatment

An interesting 4-page folder describing the use of organics in water treatment has been issued by the Power Chemicals Division of E. F. Drew & Co., Inc. It covers the theoretical and practical considerations of organics and illustrates the manner in which they overcome problems of sludge.

Zeolite Softener

Publication 4520 of the Cochrane Corp. on Cochrane Zeolite Softeners gives a detailed explanation of the sodium zeolite softening process. It includes data for laying out a softening plant, selection of zeolite material and a description of both siliceous and nonsiliceous zeolites. Also covered are the Hydromatic single-control valve and details of automatic operation. There are equipment diagrams and photos of actual installations.